USAAVLABS TECHNICAL REPORT 66-2

FLEXIBLE WING LIGHT UTILITY GLIDER

By

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G. Cota

August 1966

U. S. ARMY AVIATION MATERIEL LABORATORIES
FORT EUSTIS, VIRGINIA

CONTRACT DA 44-177-AMC-209(T)

RYAN AERONAUTICAL COMPANY
SAN DIEGO, CALIFORNIA

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The work described in this report was accomplished by the Ryan Aeronautical Company for this command under the terms of Contract DA 44-177-AMC-209(T) and was sponsored by the Advanced Research Projects Agency (ARPA). The report covers the design, fabrication, and testing of the Flexible Wing LUG.

This command concurs with the conclusions made by the contractor.

Subsequent to the testing reported herein, the Flexible Wing LUG was evaluated by the provisional 11th Air Assault Division, Fort Benning, Georgia, while conducting maneuvers. Based upon the results of this evaluation and the contractor's report, a study was initiated to determine the requirement for additional research in the towed flexible wing glider field.

Task IP121401A14172
Contract DA 44-177-AMC-209(T)
USAAVLABS Technical Report 66-2
August 1966

FLEXIBLE WING LIGHT UTILITY GLIDER

Final Report

REPORT NO. 64B139

This research was sponsored by the Advanced Research Projects Agency of the Department of Defense under ARPA No. 294, Amendment 16, and was monitored by the U.S. Army Aviation Materiel Laboratories (USAAVLABS) under Contract DA 44-177-AMC-209(T).

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ABSTRACT

This report entitled FLEXIBLE WING LIGHT UTILITY GLIDER is a final report of a program conducted by the Ryan Aeronautical Company, San Diego, California. The Contract Number was DA 44-177-AMC-209(T) and this report is USAAVLABS Technical Report 66-2 Unclassified.

Presented in this report are the results of a flight test program of a towed light utility glider system. The system was designed to carry odd-geometry cargo, and demonstrated towed flight operations up to the maximum design weight of 1500 pounds, at a velocity range extending from 30 to 70 knots indicated airspeed. Testing also included takeoff and landings on tow with helicopters, and evaluation of the flight homing system. Free flights of the light utility glider were also made carrying a payload of 800 pounds.

Presented also are the system description, and an aerodynamics and structural analysis.

Initial phases of the concept were investigated under Contracts DA 44-177-TC-779, DA 44-177-TC-807, and DA 44-177-AMC-868(T).

All flight testing was conducted at the U.S. Army Yuma Proving Ground, Yuma, Arizona, beginning 23 July 1964 and ending 17 September 1964.

CONTENTS

ILLUSTRATIONS

SYMBOLS

AERODYNAMICS

A	Wing axial force
a	Acceleration, ft./sec.^{2}
b	Flatplan span, ft.
C_A	Wing axial force coefficient, A/qS
C_D	Drag coefficient, D/qS
C_{D_o}	Drag coefficient at zero lift
C_K	Wing keel length, ft.
C_L	Lift coefficient, L/qS
C_{L_α}	Rate of change of lift coefficient with angle of attack, $dC_L/d\alpha$
C_{ℓ_β}	Rate of change of rolling moment coefficient with sideslip angle, $dC_\ell/d\beta$
C_m	Pitching moment coefficient, M/qSC_K
$C_{m_{C_L}}$	Rate of change of pitching moment coefficient with lift coefficient, dC_m/dC_L

AERODYNAMICS (continued)

C_{m_α}	Rate of change of pitching moment coefficient with angle of attack, $dC_m/d\alpha$
C_N	Wing normal force coefficient, N/qS
C_{n_β}	Rate of change of yawing moment coefficient with sideslip angle, $dC_N/d\beta$
C_{Y_β}	Rate of change side force coefficient with sideslip angle, $dC_Y/d\beta$
$C_{1/2}$	Cycles to 1/2 amplitude
D	Drag, lb.
ΔD_P	Drag component of cable tension, lb.
f	Equivalent flat-plate drag area, ft.^{2}
H.P.	Horsepower
i_w	Wing-Body incidence angle, deg.
L	Lift, lb.
M	Pitching moment
N	Wing normal force
q	Free-stream dynamic pressure, lb./ft.^{2}
R/C	Rate of climb, ft./min.
S	Flatplan wing area, ft.^{2}

AERODYNAMICS (continued)

S_G	Takeoff ground roll, ft.
S_L	Landing ground roll, ft.
t_c	Cable tension, lb.
$t_{1/2}$	Time to damp to 1/2 amplitude, sec.
V	Velocity, ft./sec. or k.
V_S	Stall velocity, k.
V_{trim}	Trim velocity, k.
W	Weight, lb.
ΔW	Weight component of cable tension, lb.
α_B	Body angle of attack, deg.
α_W	Wing angle of attack, deg.
β	Sideslip angle, deg.
γ	Flight path angle, relative to horizon, deg.
θ_H	Cable angle at helicopter, relative to horizon, deg.
θ_{LUG}	Cable angle at LUG, relative to horizon, deg.
μ_B	Braking-friction coefficient

AERODYNAMICS (continued)

ρ	Air density, slugs/ft.^{3}
σ	Air density ratio

STRESS AND LOADS

A	Area, in.^{2}
$C_{N_{Max}}$	Maximum normal force coefficient
D	Diameter, in.
E	Modulus of elasticity, psi
F_b	Allowable bending stress, psi
F_{cc}	Allowable column stress, psi
F_{C_R}	Allowable compression buckling stress, psi
F_{C_Y}	Allowable compression yield, psi
F_{CO}	Column yield stress, psi
$F_{S_{CR}}$	Allowable shear buckling stress, psi
f_b	Bending stress, psi
f_c	Column stress, psi

f_{s_t}	Torsional shear stress, psi
G	Shear modulus, psi
G.W.	Gross weight, lb.
g	Acceleration of gravity, ft./sec.^{2}
I	Moment of inertia, in.^{4}
J	Polar moment of inertia, in.^{4}
K, k	Dimensionless coefficient
L, ℓ	Length, in.
M	Moment, in.-lb.
M.S.	Margin of safety
N	Load factor
N_g	Gust load factor
N_z	Vertical load factor
P	Force, lb.
P_{CR}	Allowable buckling load, lb.
q	Dynamic pressure, lb./ft.^{2}
S_t	Tail area, ft.^{2}

STRESS AND LOADS (continued)

T	Torque, in.-lb.
t	Thickness, in.
U_{d_e}	Gust velocity, fps
V	Velocity, k.
V_e	Equivalent airspeed, k.
V_G	Gust velocity, k.
V_H	Maximum level speed, k.
V_L	Limit speed, k.
V_R	Resultant velocity, k.
V_S	Stall speed, k.
W	Weight, lb.
Y_t	Tail side force, lb.
Z	Section modulus, in.^{3}
α_w	Angle of attack, wing, deg.
β	Sideslip angle, deg.
ρ_o	Sea level atmospheric density, slugs/ft.^{3}

STRESS AND LOADS (continued)

ρ	Radius of gyration, in.
θ	Torsional deflection, angular

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INTRODUCTION

The concept of the Flexible Wing Light Utility Glider (LUG) was based on the operational requirement that an extremely versatile aerial cargo delivery vehicle of simple design and low cost was urgently needed by the U.S. Army for use in a highly mobile and dispersed combat environment. The design concept of the LUG system includes simplicity of construction, ease of maintenance, interchangeability, off-the-shelf components, and a design philosophy of cost effectiveness.

Preliminary design studies and the final detail design of a Flexible Wing Light Utility Glider were accomplished, and four test vehicles were fabricated. Structural integrity was determined by stress analysis, and the performance and stability were determined by aerodynamic analysis. A flight test program determined handling qualities and performance of the vehicle. Initial ground taxi tow tests revealed excellent tracking and braking characteristics. All vehicles were utilized in both the ground and flight tests.

Thirty-three flight test operations were conducted on the LUG during 23 July 1964 through 17 September 1964. The towed flight envelope was expanded to a speed range of 30 to 70 KIAS, depending upon the gross weight and wing-incidence angle. Payloads of up to 1500 pounds were successfully towed. Eight free flights were also made. Manual control was achieved in free flight after making several control system modifications. Payloads of up to 800 pounds were successfully free flown. Stability and control in free flight were not fully investigated; further flight testing is required.

CONCLUSIONS

The results of the flight test program have demonstrated the adaptability of the LUG system to the requirements of the U.S. Army. The versatility of the s, tem to carry odd-geometry cargo has been clearly demonstrated also.

The flight performance characteristics satisfied all expectations for towed missions. Takeoff and landing maneuvers on tow with the H-34 or the UH-1b helicopter did not present any serious problems and were highly successful. Towed flight operations could be conducted with payloads up to the maximum design weight of 1500 pounds. The velocity envelope over the weight range extended from 30 to 70 knots indicated airspeed. The free flight performance characteristics were only partially obtained due to the limited number of flights. The existing homing flight system was unsatisfactory with the LUG configurations tested in this program. The primary reason for the unsatisfactory homing characteristics was attributed to the poor roll control resolution of the LUG. Although modifications were made to correct this deficiency, additional homing flights were not attempted. Flare landings made while the LUG was in a turn, as would be the case for a complete homing flight, were not completely investigated.

While the LUG satisfactorily demonstrated its ability to carry full payloads under ambient conditions during flight test operations, further testing is required to determine reasonable gust factors for application to flexible wing aircraft before it can be concluded the LUG is structurally capable of carrying the design payload.

It is concluded that additional testing is required with the Flexible Wing Light Utility Glider in order to determine the performance of the system. The necessary tests are:

- Expansion of launch parameters for free-flight operations.
- Investigation of maneuverability under tow.

- Development of an improved homing mode flight control system.
- Investigation of the landing flare system characteristics, including landings in turns.

SYSTEM DESCRIPTION

LIGHT UTILITY GLIDER

The Ryan Model 180 Light Utility Glider (LUG), Figures 1 and 2, is a radio-controlled vehicle with a flat platform body attached to a foldable flexible wing. The LUG, carrying a 1,000-pound cargo load, is designed to be towed to the cargo delivery area by a helicopter and released for a radio-controlled free flight to touchdown in the landing area. The LUG may also be towed to touchdown by the helicopter, in which case the carrying capacity may be increased to 1500 pounds.

When released from the helicopter in the predetermined drop area, the unmanned glider will descend in radio-controlled flight to touchdown. The LUG may be controlled by a radio homing signal transmitted from the touchdown area, or by command control radio signals transmitted from the touchdown area, or from a vantage point on the ground remote from the touchdown area.

Light Utility Glider Body

The light utility glider body, Figure 3, which is the main support structure of the LUG vehicle, is 96 inches long and 68.8 inches wide, with an internal depth of 6 inches. The body houses the radio, electrical, and mechanical control equipment on the cargo carrying platform. The body also supports the rolling gear, skid assembly, wing attachments, and towing bridle attachments.

The rolling gear consists of four air-inflated rubber-tired wheels attached to four body-mounted steel leaf springs. The two front wheels are castered and cambered. A self-centering device is employed to yield proper landing roll-out. The rear wheels are fitted with Bendix mechanical brakes, which reduce the roll distance after touchdown. The brakes are loaded by a common load spring. Brake cables from the operating levers on the brake assemblies lead through guide holes, directional pulleys, and brake unloading levers to the spring. Turnbuckles are provided to adjust the individual brake cables and to adjust the spring load. The spring exerts a load of approximately 90 psi on the brakes when expanded approximately 2 inches. Two levers in the brake system are so arranged that moving them to the brake-off position lengthens the effectiveness of the brake cables about 3 inches, completely relaxing the spring and unloading the brakes. A ring and cable to unload the brakes are provided, with an arrangement for securing the brakes in the brake-off position to facilitate ground handling of the LUG.

The skid assembly consists of two 4-by-4-by-96-inch Douglas fir planks, faced with 0.125-by-3.620-by-96-inch aluminum alloy slide sole plates. The planks are mounted longitudinally under each side of the body to receive the shock load produced when the rolling gear springs let the vehicle bottom-out during landings.

Wing Assembly

The wing assembly, Figure 4, which supports the LUG in flight, is a foldable flexible type made up of a rigid keel, two rigid leading edges, a rigid spreader bar, flexible fabric membrane, fittings, and attaching hardware. The forward ends of the leading edges attach to the forward end of the keel to form an apex. The spreader bar, which attaches to the keel at keel station 140, supports the leading edges to produce the proper sweep angle.

The rigid wing keel, approximately 19 feet long, is made up of three sections of aluminum alloy tubing. The forward and aft keel sections of 3.5-inch-OD (outside diameter) tubing telescope into the center section of 4.0-inch-OD tubing to a 10-inch lap at each joint. The joints are pinned with 0.5-inch round stock retained in position with washers and pins. Cotter pins in the aft joint provide for easy removal when the aft wing surface is folded for transportation purposes. Pivot attachments at keel stations 75.0 and 135.6 for attaching the wing assembly to the glider support struts, and a fitting at keel station 140.25 for attaching the spreader bar to the keel assembly are a part of the keel center section assembly. The keel forward section assembly is fitted with a cone-shaped wooden plug, to close the forward end and with a pivotal axle at keel station 3.5 for attaching the wing leading edges. The aft keel section is a 3.5-inch-OD by 85-inch-long tube drilled at the forward end for pinning to the center section assembly and drilled at keel stations 178.97 and 217.5 for attaching a fin.

The rigid wing leading edges, which are identical units approximately 18.5 feet long, are each made up of three sections of aluminum alloy tubing. The forward and aft leading edge sections of 3.0-inch-OD tubing telescope into the center section of 3.25-inch-OD tubing to a 10-inch lap at each joint. Joint pins of 0.5-inch diameter are retained with washers and pins. Cotter pins in the aft joints provide easy removal when the wing is folded for transportation purposes. The forward leading edge section, a welded assembly of the forward tube and a formed liner, provides reinforcing for the leading-edge-to-keel hinge joint. The aft leading edge sections are drilled at leading edge stations 175.00, 181.00, and 185.00 to accommodate the spreader bar fitting pins.

The spreader bar, 19.8 feet long, is made up of three sections of aluminum alloy tubing. The two identical outboard sections of 2.5-inch-OD by 118.8-inch-long tubing telescope into the center section of 2.75-inch-OD by 48-inch-long tubing to form a 24-inch lap at the joints. The joint pins are secured in place with washers and lock pins. Fabricated, opposite-hand fittings that bolt to the leading edges are pinned to the outboard ends of the spreader bar to form a flexible joint. The center section of the spreader bar is attached to the keel assembly with a clevis joint pin.

The wing membrane is made up of panels of 3.5-ounce olive drab Dacron fabric that is coated on both sides with neoprene (3M designation ND 3206), which increases the total weight to 6 ounces. The panels are sewn together with size F Nylon thread using 5 to 6 zigzag stitches per inch to form a continuous membrane of 250 square feet. Sleeve-like pockets in the forward edges and at the forward and aft centerline slide over the leading edges and the keel. The membrane has reinforced cutouts at the leading edges and keel joints for installation and removal access to pins and bolts.

The wing support structure of six struts and hardware attach the LUG wing assembly to the body. Two struts, assembled as an A-frame, attach to the wing keel at the forward attaching point and to the two forward corners of the LUG body. Four struts attach to the four body corners and to the pivot block, which, in turn, attaches to the wing keel pivot point.

The fin assembly, Figure 5, which stabilizes the vehicle in flight, attaches to the [illegible] at keel stations 178.97 and 217.50. The fin is made up of a 0.020-inch cla[illegible]uminum alloy skin; the skin is formed over spars and ribs to produce an airfoi[illegible] with a leading edge of 61.8 inches from keel to tip chord, a trailing edge of [illegible] inches from keel to tip chord, and a tip chord of 21 inches from leading edge to trailing edge.

Control Equipment

Signals required to control the LUG when being towed by the helicopter are initiated at the pilot's control panel. The electrical control signals are transmitted to the LUG through a jacketed multiconductor (13 No. 22 wire conductor) cable attached to the 3/16-inch diameter steel tow cable.

Signals required to control the LUG after it is detached from the helicopter are activated remotely by signals from a radio control transmitter. Transmitted radio signals, received by the control radio receiver, are passed through selective filters to produce signals which operate logic relays to produce electrical control signals.

Electrical control signals received at the LUG control system are sequenced and routed to the various control components by relays in the relay box.

Radio Receiver

The radio receiver, Figure 6, is completely solid state and of modular construction to facilitate field repairs. The receiver power supply and schematic block diagram are shown in Figures 7 and 8.

The radio receiver case is 8.3 by 7.5 by 4 inches, and the separate receiver power supply is 8.3 by 7.5 by 4 inches. The receiver consists of two identical superheterodyne receivers with a common local oscillator, summed automatic gain control, and a control logic system. During homing operations, the 139.1-megacycle control carrier is amplitude modulated by a 2500-cps audio signal. The modulated 139.1-megacycle signal received at each of the two receiving antennas is amplified at radio frequency, converted to an intermediate frequency (i.f.), amplified and demodulated to audio frequency. The 2500-cps audio frequency is fed to the logic relays through selective band-pass filters, energizing homing relay K1. The signal from the i.f. amplifier is also fed through the gating network to the differential detectors. The audio voltage, from the filter drive amplifier, triggers the post detection gate and activates either "left" turn relay K6 or "right" turn relay K7 in response to the unbalance of the signals. Command signals received at the antenna are amplified at radio frequency, converted to i.f., amplified and demodulated to audio frequency. The audio frequency is passed through a network of selective band-pass filters which pass the signal only to the relay corresponding to the specific command function frequency.

Helicopter Control Panel

The helicopter control panel shown in Figure 9 is installed in the helicopter, within easy reach of the pilot, as part of the helicopter modification kit. The panel, which contains switches to initiate signals and functional lights, uses helicopter electrical power to energize control function relays in the LUG. Switches to initiate signals for GLIDER POWER ON, WING INCIDENCE DOWN, WING INCIDENCE UP, GLIDER RELEASE, and CABLE RELEASE and lights to indicate GLIDER POWER ON, WING INCIDENCE DOWN, WING INCIDENCE UP, and GLIDER RELEASE are provided.

Relay Box

Electrical signals received from the radio receiver logic relays or from the helicopter control panel are passed to the relay box, Figure 10, then to the various electromechanical control components. The relay box contains control and time delay relays which combine and sequence the received signals to produce required control.

Light Utility Glider Control Signals

The control and test signals are shown schematically in Figure 11.

Glider Power

The GLIDER POWER ON signal is initiated at the helicopter control panel. When the GLIDER POWER toggle switch S-1 is placed in the ON position, power from the helicopter bus energizes LUG relay K10. Closed contacts of energized relay K10 energize relay K1 with helicopter bus power. Energized relay K1 closes the LUG battery power contacts. The closed battery contacts apply LUG battery holding power to relays K1 and K10 through blocking diode CR1 and energizes the GLIDER POWER ON indicator light on the helicopter control panel. The LUG battery power also supplies power to relay contacts required for the various control functions and energizes relay K15, which connects the radio receiver power supply to energize the radio.

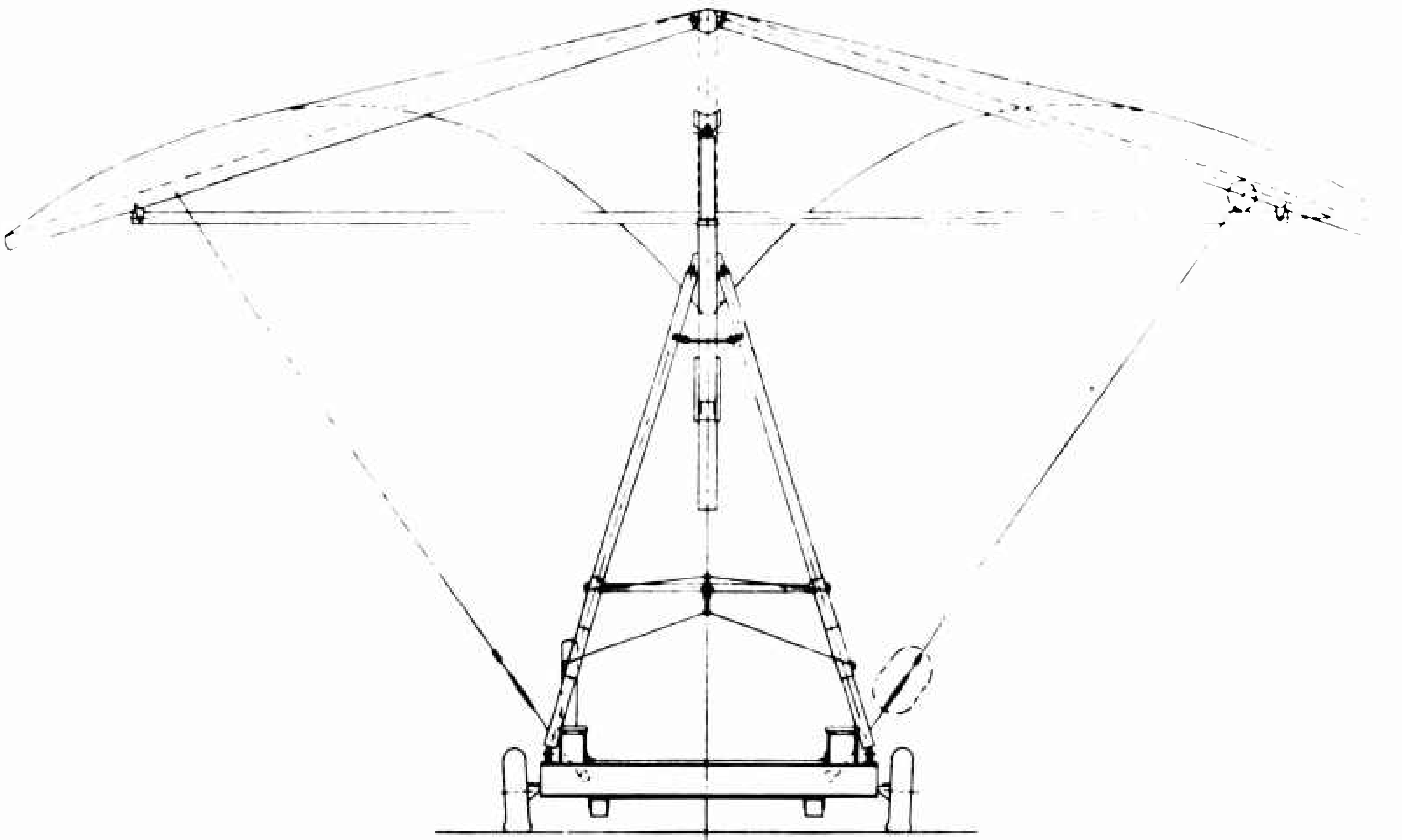
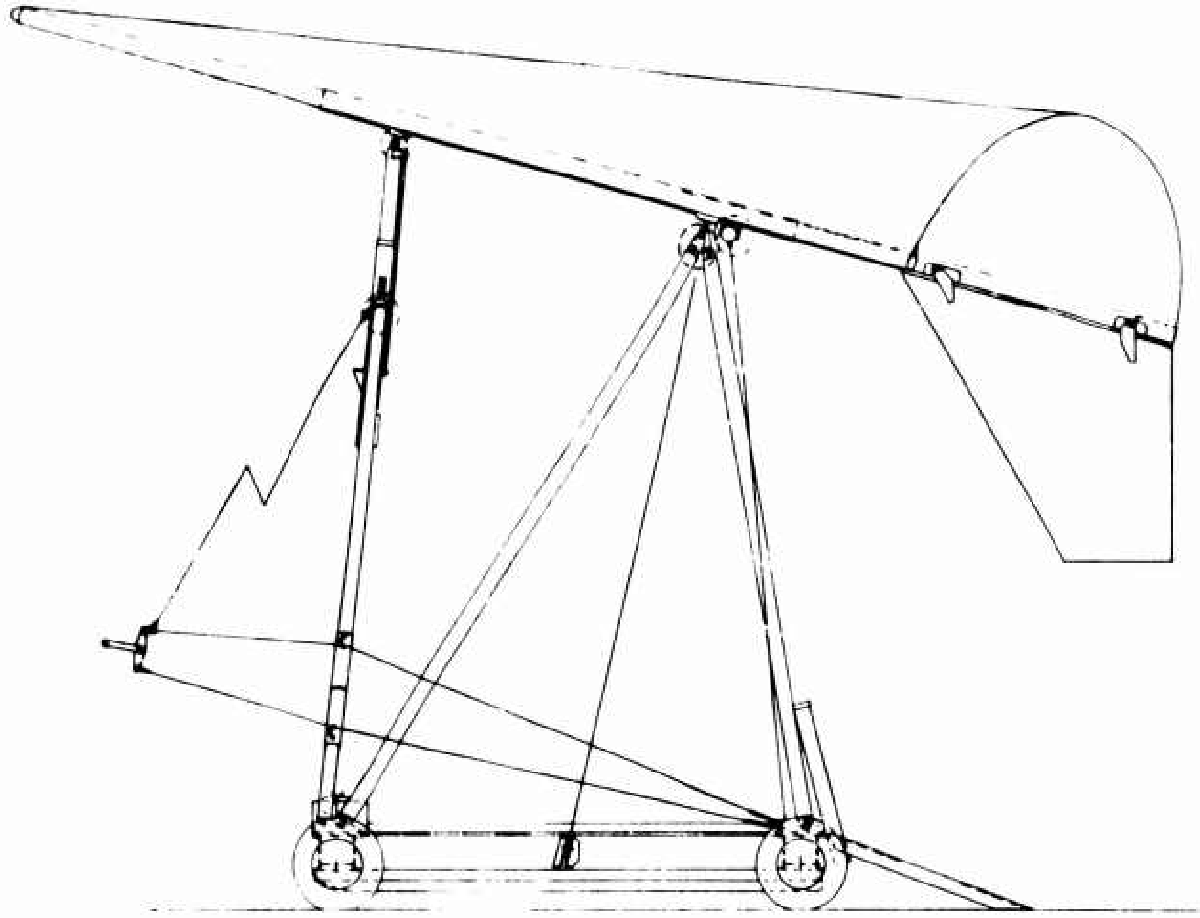


Figure 1. Two-View, Light Utility Glider



VIEW LOOKING INB'D · L H SIDE

FWD

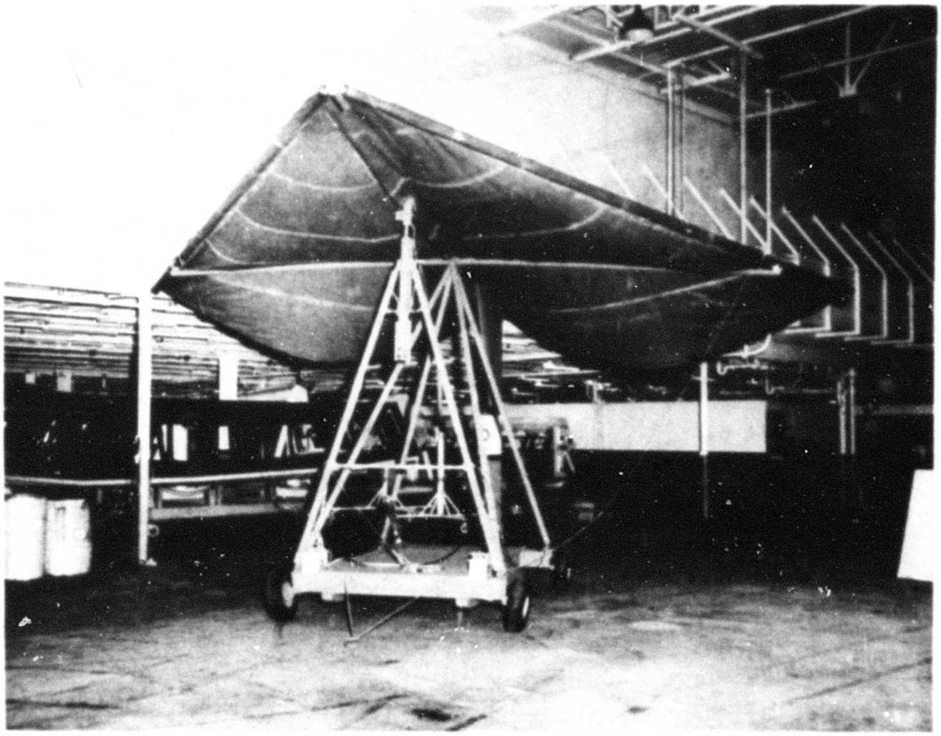


Figure 2. Ryan Model 180 Light Utility Glider

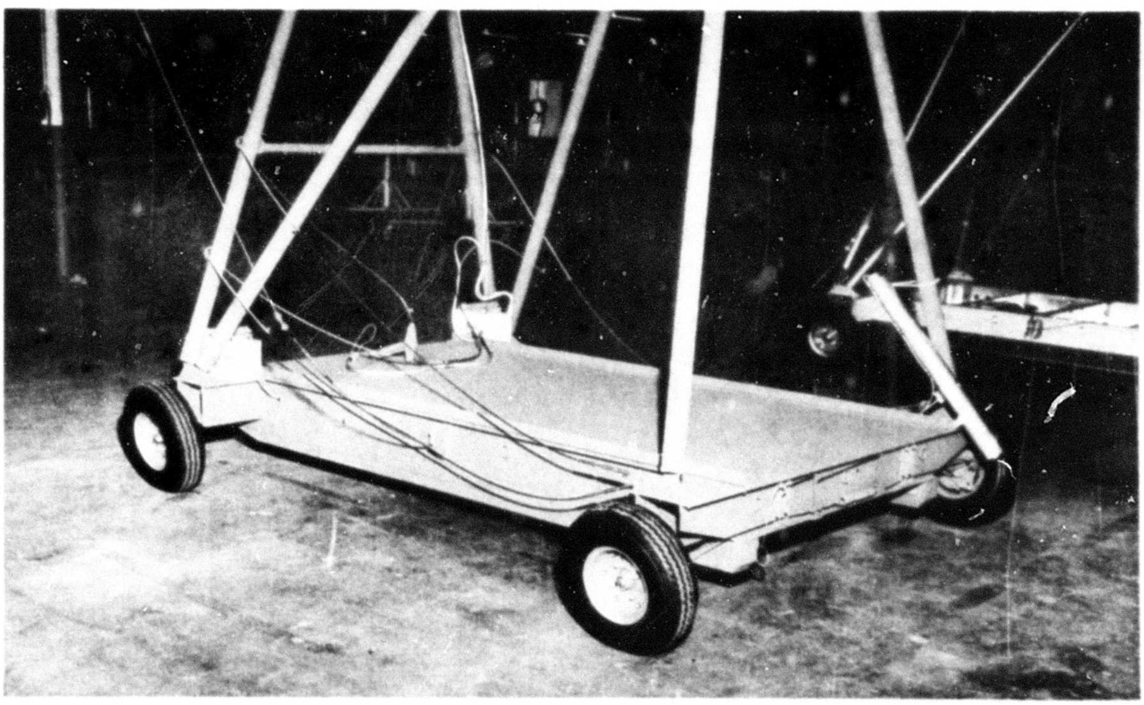


Figure 3. Light Utility Glider Body

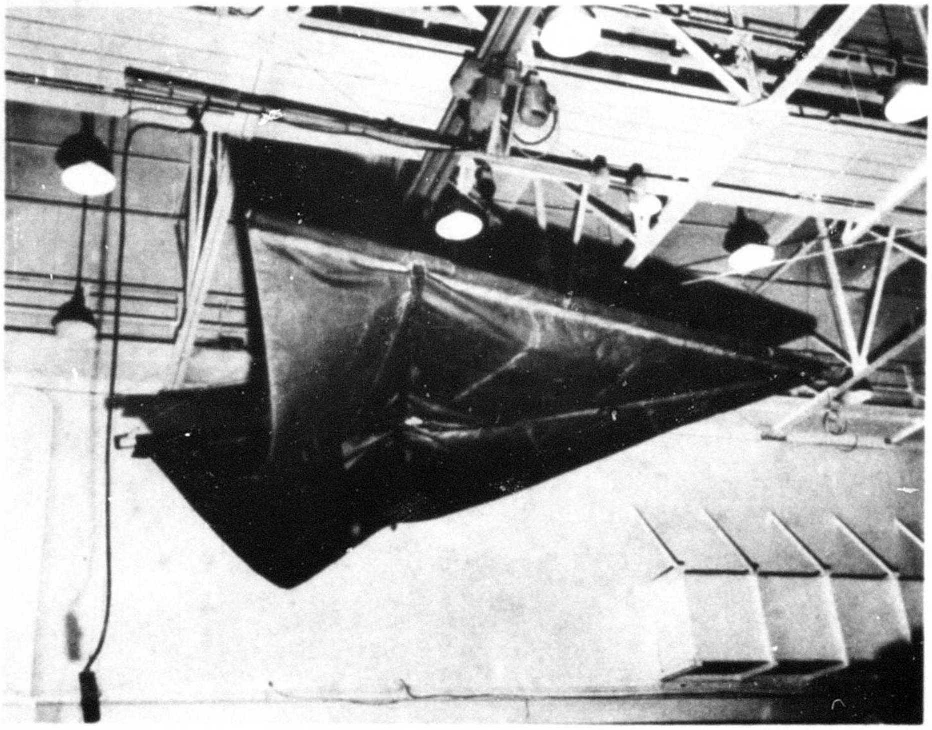


Figure 4. Wing Assembly

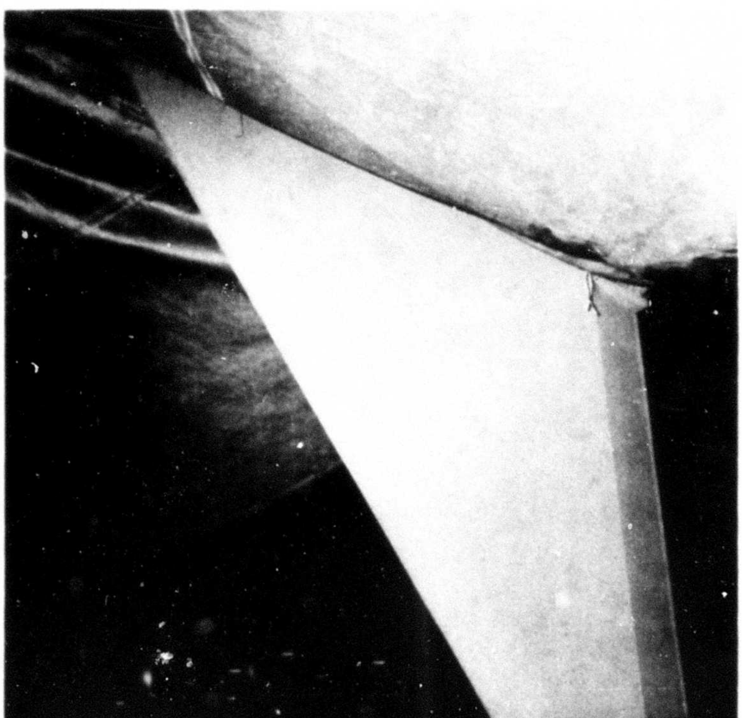


Figure 5. Fin Assembly

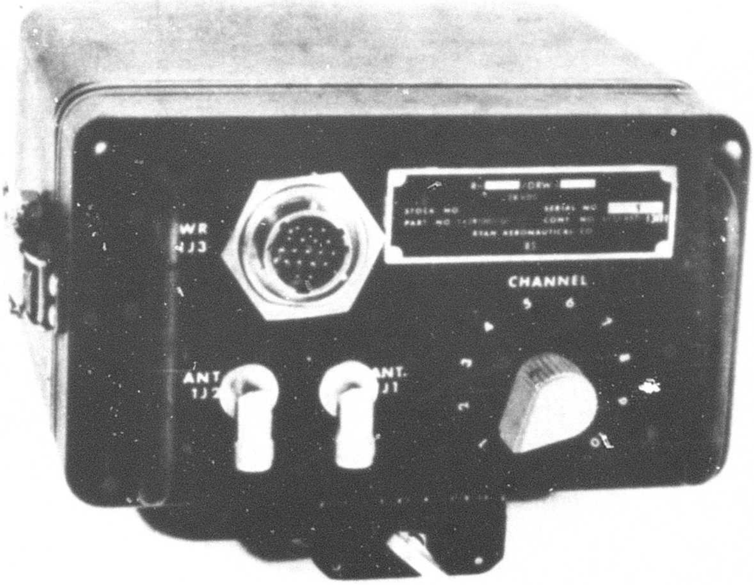


Figure 6. Radio Receiver

Figure 7. Receiver Power Supply

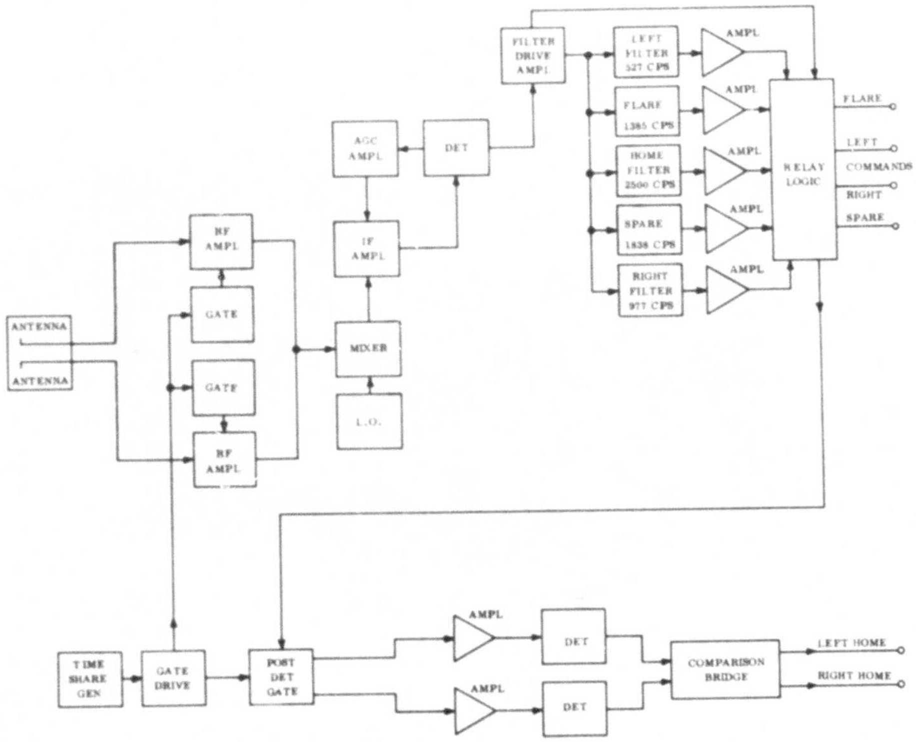


Figure 8. Radio Receiver, Block Diagram

Figure 9. Helicopter Control Panel

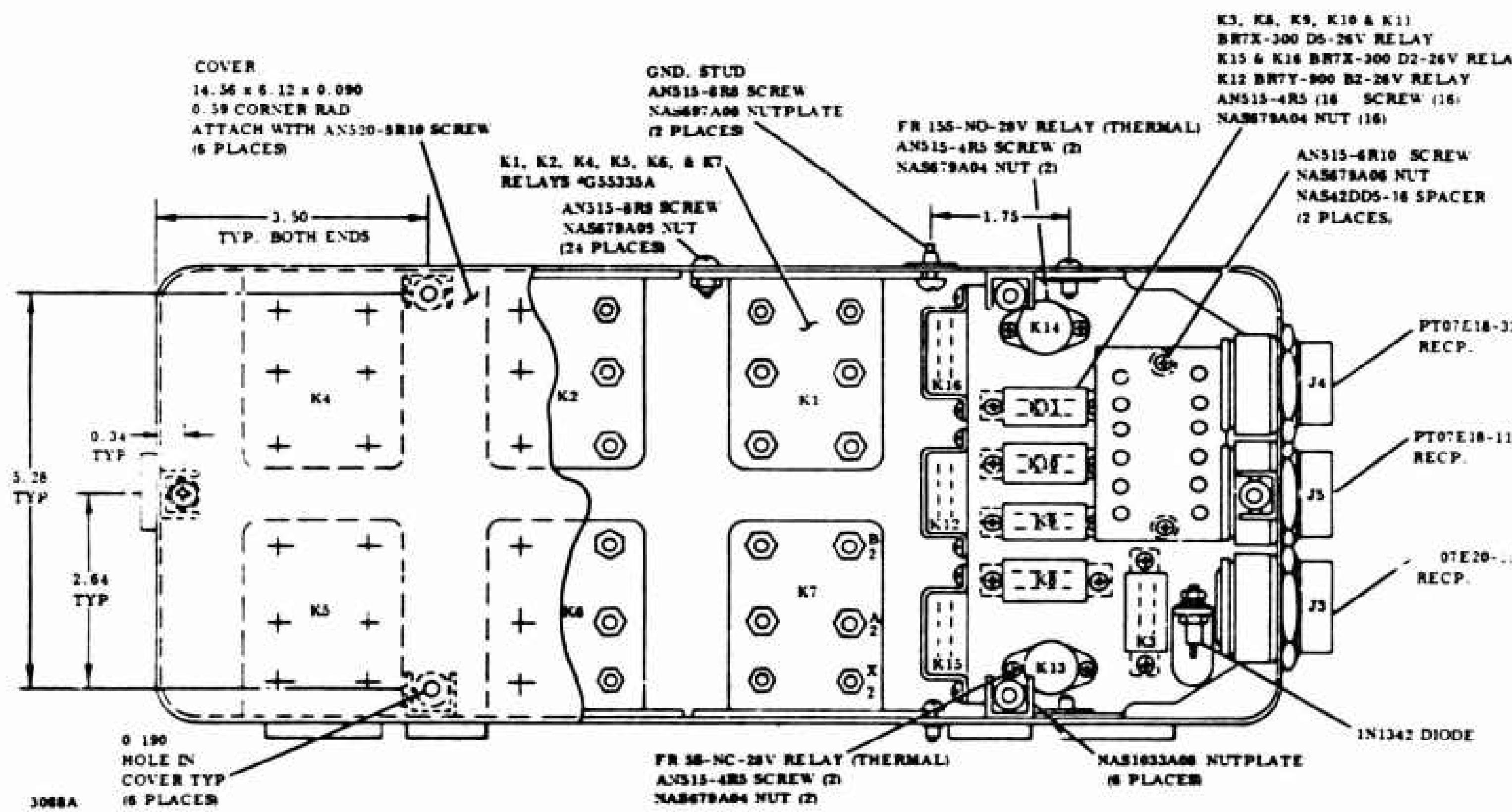


Figure 10. Relay Box

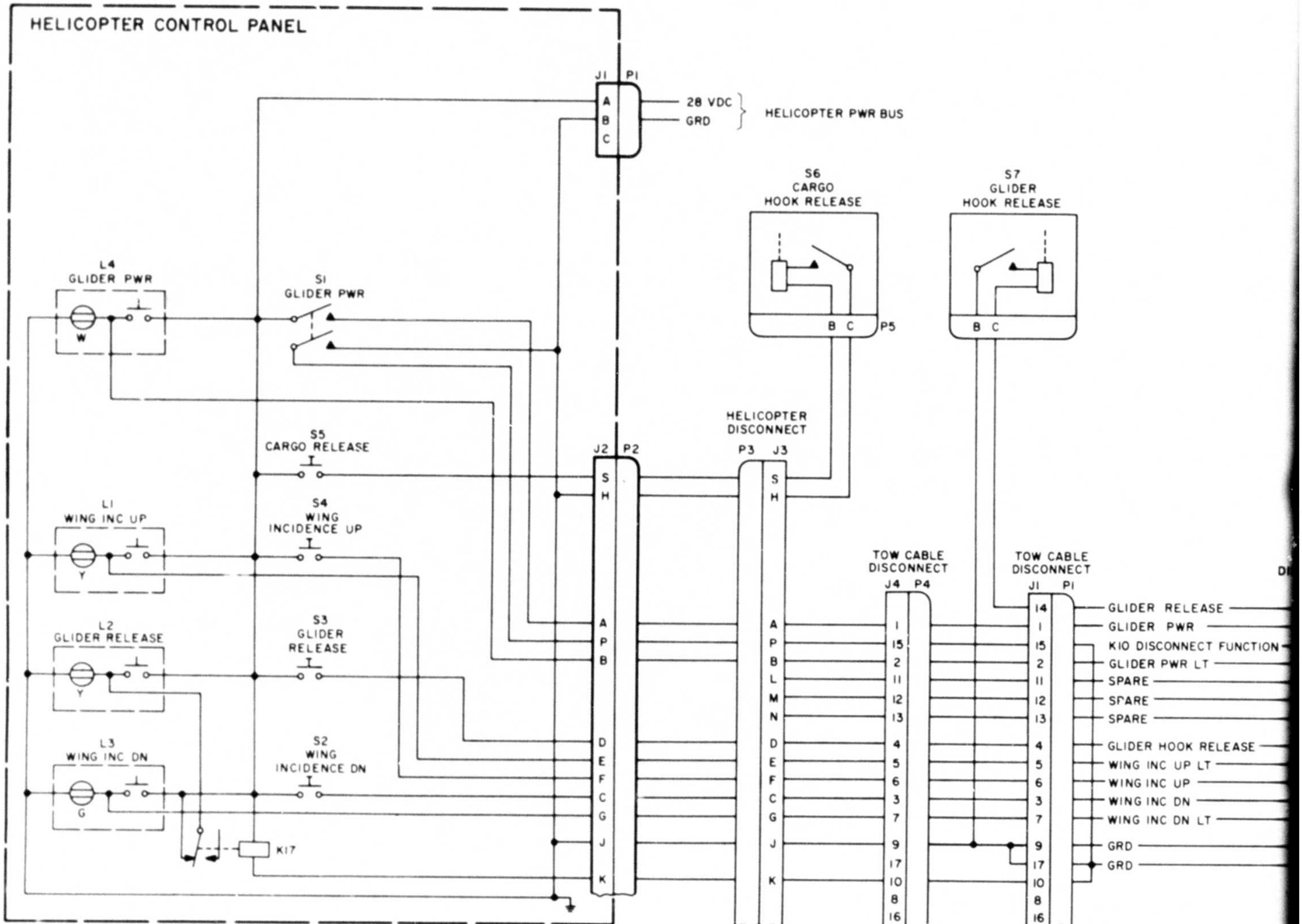
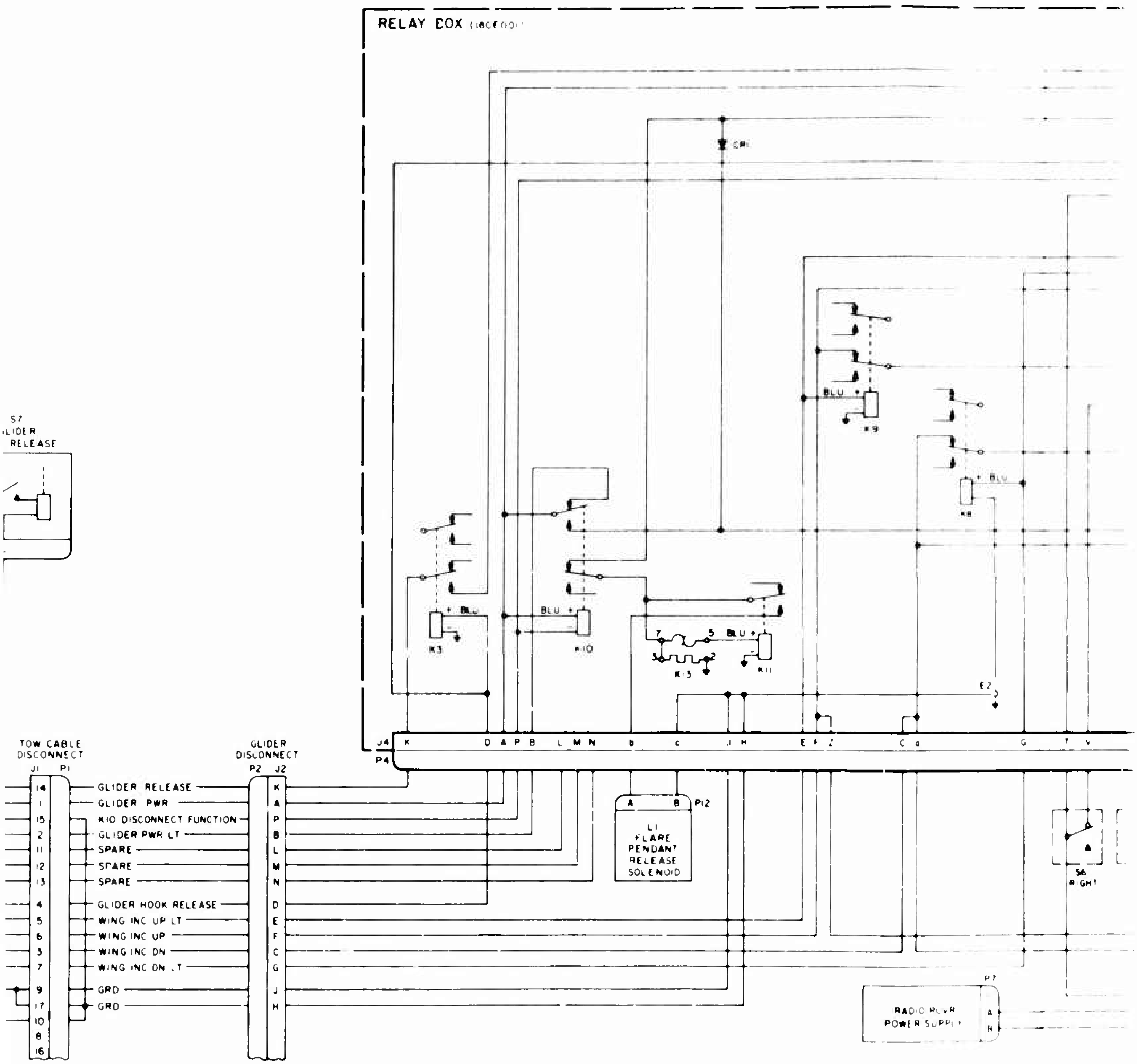


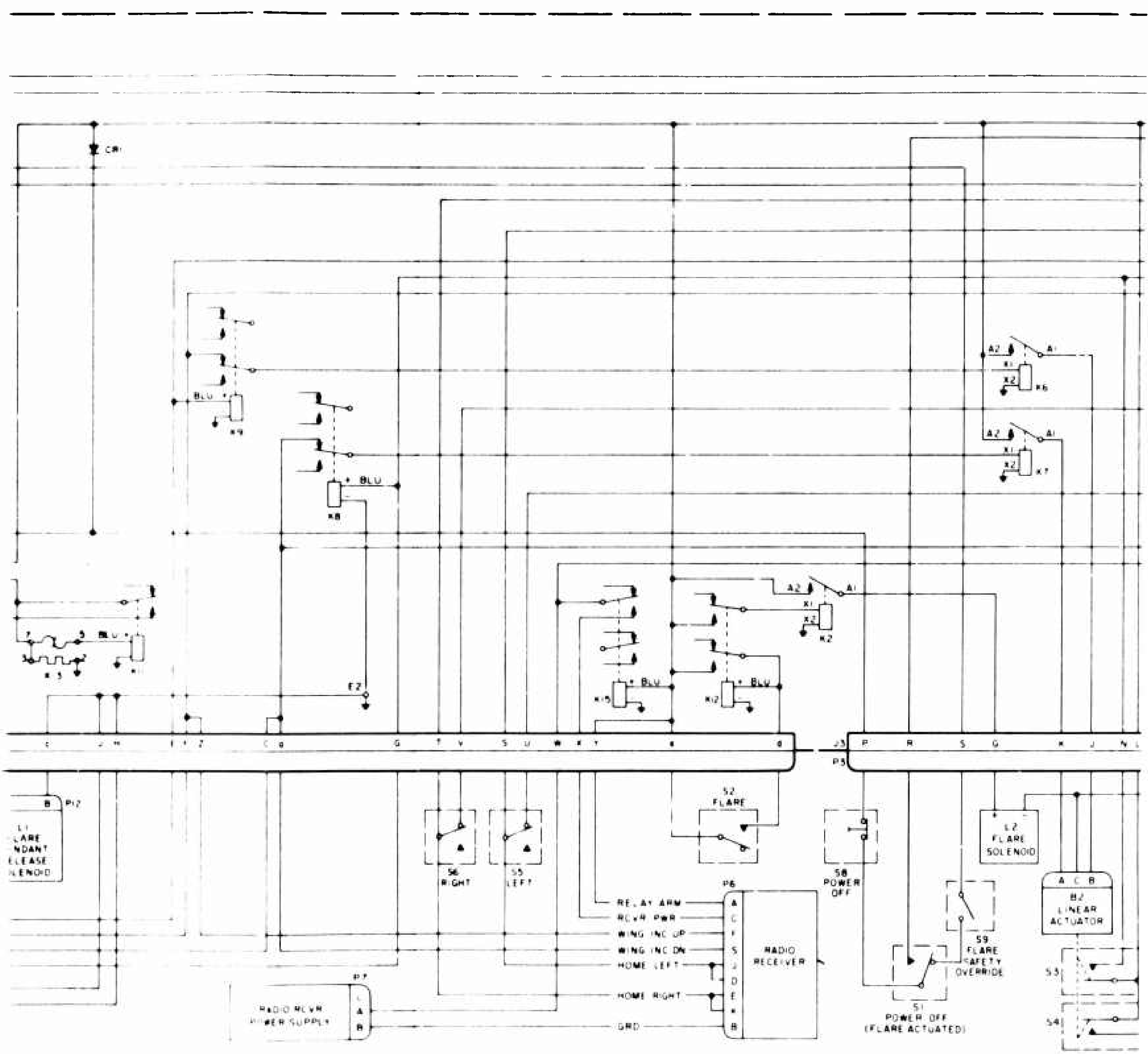
Figure 11. Schematic Electrical Diagram, Control and Test

A

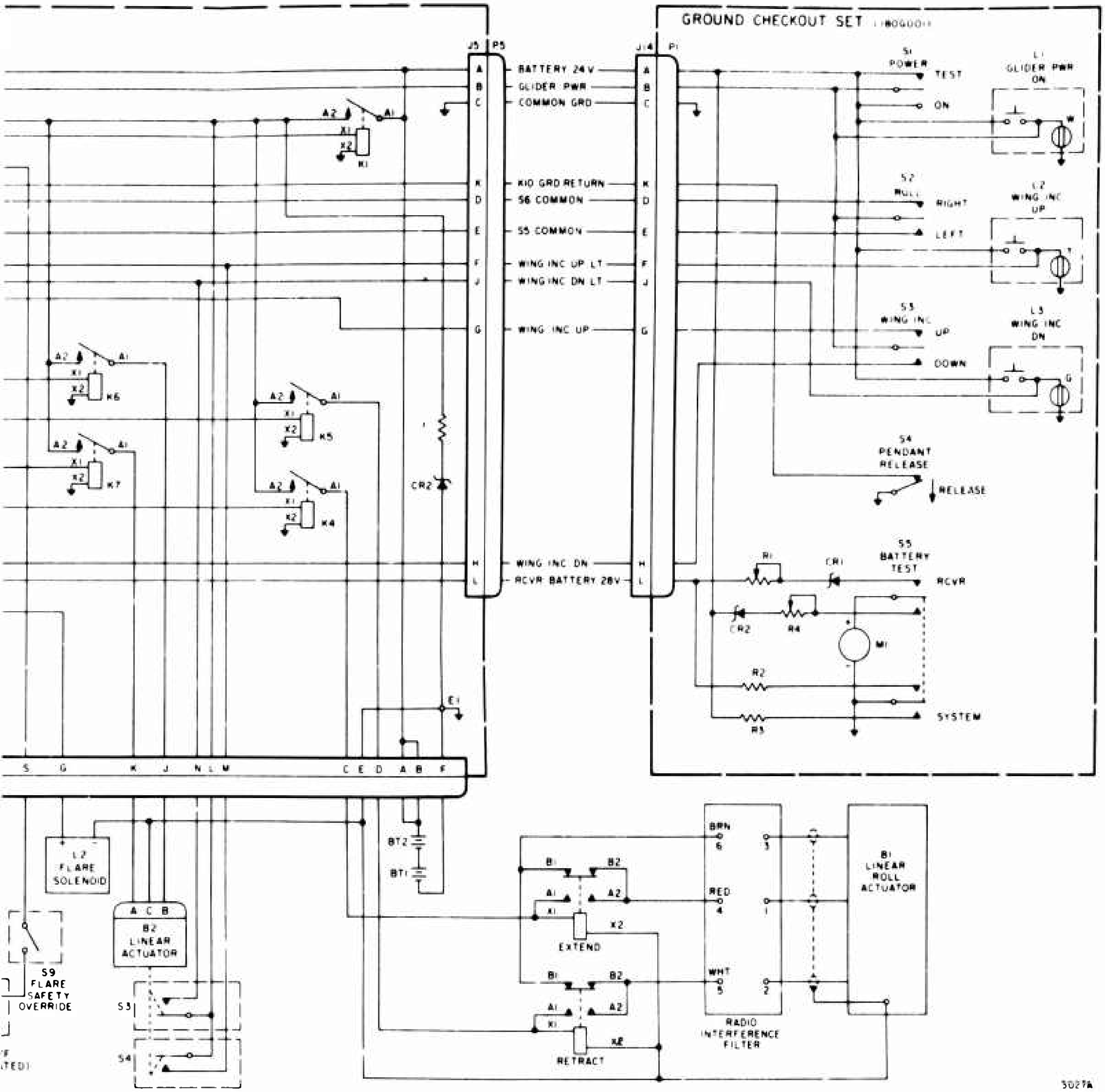


RELAY BOX
S7
GLIDER
RELEASE
K3
K10
K11
K13
K9
K8
CR1
BLU
E2
J4
P4
TOW CABLE
DISCONNECT
J1
P1
GLIDER
DISCONNECT
P2
J2
GLIDER RELEASE
GLIDER PWR
K10 DISCONNECT FUNCTION
GLIDER PWR LT
SPARE
SPARE
SPARE
GLIDER HOOK RELEASE
WING INC UP LT
WING INC UP
WING INC DN
WING INC DN LT
GRD
GRD
P12
L1
FLARE
PENDANT
RELEASE
SOLENOID
S6
RIGHT
P7
RADIO RCVR
POWER SUPPLY

B



CR1
K9
BLU
K8
K6
K7
K2
K15
K12
E2
J3
P3
P12
S6
RIGHT
S5
LEFT
S2
FLARE
S8
POWER
OFF
L2
FLARE
SOLENOID
B2
LINEAR
ACTUATOR
S9
FLARE
SAFETY
OVERRIDE
S1
POWER OFF
(FLARE ACTUATED)
P6
RELAY ARM
RCVR PWR
WING INC UP
WING INC DN
HOME LEFT
HOME RIGHT
GRD
RADIO
RECEIVER
P7
RADIO RCVR
POWER SUPPLY
S3
S4


GROUND CHECKOUT SET
J5
P5
J14
P1
BATTERY 24 V
GLIDER PWR
COMMON GRD
K10 GRD RETURN
S6 COMMON
S5 COMMON
WING INC UP LT
WING INC DN LT
WING INC UP
WING INC DN
RCVR BATTERY 28V
S1
POWER
TEST
ON
L1
GLIDER PWR
ON
S2
RIGHT
LEFT
L2
WING INC
UP
S3
WING INC
UP
DOWN
L3
WING INC
DN
S4
PENDANT
RELEASE
RELEASE
S5
BATTERY
TEST
RCVR
SYSTEM
R1
CR1
CR2
R4
M1
R2
R3
K1
K4
K5
K6
K7
CR2
E1
BT2
BT1
L2
FLARE
SOLENOID
B2
LINEAR
ACTUATOR
S9
FLARE
SAFETY
OVERRIDE
S3
S4
EXTEND
RETRACT
BRN
RED
WHT
RADIO
INTERFERENCE
FILTER
B1
LINEAR
ROLL
ACTUATOR

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D

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Pitch

WING INCIDENCE DOWN and WING INCIDENCE UP electrical control signals may be initiated at the helicopter control panel or in the radio receiver logic relays in response to remote radio control signals.

A WING INCIDENCE DOWN signal from either source passes through closed contacts of de-energized relay K8 to energize relay K7. LUG battery power actuated by the GLIDER POWER ON signal passes through closed contacts of energized relay K7 to energize pin A of linear actuator B2, causing it to move in the wing-down direction. If moved to the full down position, limit switch S3 closes. Glider battery power passes through closed contacts of switch S3 to energize relay K8. Energized relay K8 opens contacts which supply power to relay K7 to de-energize Linear Actuator B2. When connected to the tow helicopter, the closed contacts of switch S3 also supply power to the WING INCIDENCE DOWN green indicator light.

A WING INCIDENCE UP signal from either source passes through closed contacts of de-energized relay K9 to energize relay K6. LUG battery power actuated by the GLIDER POWER ON signal passes through closed contacts of energized relay K6 to energize pin B of the linear actuator B2, causing it to move in the wing-up direction. If moved to the full up position, limit switch S4 closes. Glider battery power passes through closed contacts of switch S4 to energize relay K9. Energized relay K9 opens contacts which supply power to relay K6 to de-energize linear actuator B2. When connected to the tow helicopter, the closed contacts of switch S4 also supply power to the WING INCIDENCE UP yellow indicator light.

Roll

Left and right roll electrical signals are initiated at the roll control logic relays in the radio receiver.

A roll LEFT signal passes through the normally closed contacts of limit switch S5 to energize relay K4. Closed contacts of energized relay K4 pass LUG battery power, activated by the GLIDER POWER ON signal, to pin A of linear actuator B-1, causing it to move to the wing-left direction as long as the signal is maintained. If the adjusted limit is reached, switch S5 opens to de-energize relay K4. Whenever roll control power is removed, the actuator holds the attained roll attitude.

A roll RIGHT signal passes through the normally closed contacts of limit switch S6 to energize relay K5. Closed contacts of energized relay K5 pass LUG battery power, actuated by the GLIDER POWER ON signal, to pin C of linear actuator B1, causing it to move to the wing-right direction as long as the signal is maintained. If the adjusted limit is reached, switch S6 opens to de-energize relay K5. Whenever roll control power is removed from the actuator, the attained roll attitude is maintained.

For flight test purposes only, additional homing limit switches were provided to reduce turn rates in the homing mode.

Glider Release

The glider release signal is initiated at the helicopter control panel. When GLIDER RELEASE switch S3 is pressed, power from the helicopter energizes LUG relay K3. Closed contacts of energized relay K3 pass LUG battery power, activated by the GLIDER POWER ON signal, to the glider hook release switch S7 to open the hook and release the glider. When the hook releases, a microswitch closes the circuit to light the yellow GLIDER RELEASE indicator light on the helicopter control panel. Releasing the glider opens the circuits to all indicator lights except the GLIDER RELEASE light. Releasing the glider also opens the ground return from relay K10. Closed contacts of de-energized relay K10 energize relay K11 after approximately 15 seconds through closed contacts of energized time delay relay K14 and closed contacts of de-energized time delay relay K13 and the coil of relay K13. Closed contacts of energized relay K11 energize pendant release solenoid L1 with LUG battery power. Energized solenoid L1 releases the flare switch to pay out into flight position below the LUG. Energized time delay relay K13 runs out after 5 seconds to de-energize relay K11, cutting off power to solenoid L1.

Flare

As the LUG approaches towed touchdown, the suspended flare (impact) switch S2 strikes the ground and closes, thereby energizing relay K12. One set of closed contacts of energized relay K12 completes a lock-in circuit, and the second set of closed contacts energizes relay K2. Closed contacts of energized relay K2 complete the circuit to energize flare solenoid L2, which releases the wing to flare position. The flared wing moves two-position limit switch S1 from the normally closed to the normally open position, which turns normal LUG system operating power OFF and energizes relay K3 using helicopter power through the GLIDER POWER ON line and the normally open contact of S1. Contacts of energized relay K3 close a circuit from the battery side of relay K1 to energize glider hook release switch S7 with LUG power.

SUPPORT EQUIPMENT

Support equipment included in this section is that equipment required for optimum use of the Light Utility Glider. Included is the description and modification of the towing helicopter and a description of the tow cable, radio control transmitter, and ground handling equipment.

Towing Helicopter

The helicopter (Figure 12) selected for towing the LUG is the Army UH-1B. The modification necessary to equip the UH-1B helicopter to tow the LUG is available in kit form as Ryan Part 179V100. The kit provides for installing a helicopter control panel in the pilot's cockpit, attaching tow bridle supports to existing right and left side fittings at helicopter stations 123.3 and 148.7, modifying the existing foot-operated manual cargo release mechanism to function as a manual tow cable release, and installing guards at the helicopter skid and tail rotor. In addition to the supplied kit, an electrical connection was made to a switch on the pilot's control stick to provide the pilot with an electrical tow cable release which supplemented his manual release mechanism. For installation details, refer to the kit drawings.

Tow Cable

The tow cable is approximately 400 feet long and consists of a 3/16-inch steel tow cable and a multiple conductor electric cable enclosed in a scuff-resistant outside jacket. The mutliple conductor contains 13 No. 22 wires. The helicopter end of the tow cable is swaged to a terminal which attaches to an eye fitting through a weak link designed to fail at 3000 + 250 - 0 pounds. The multiple conductor terminates in a quick-disconnect type electrical connector. The tow load end of the cable is swaged to a terminal which connects to load disconnect hook Part SP4100. Two conductors, of the multiple conductor cable, break out and rout to the disconnect hook control solenoid receptacle plug. Remaining conductors terminate in a disconnect receptacle mounted on the hook assembly.

Radio Control Trasmitter

The radio control transmitter (Figure 13) is completely solid state and is powered by a self-contained rechargeable battery power supply or by a 28-volt dc external power source. The transmitter block diagram is shown in Figure 14.

The battery power supply has approximately 6 hours use-life without recharging, equal to approximately 24 maximum range recoveries. The transmitter is made up of plug-in modules and consists of a selectable-crystal-controlled oscillator, tone generators, and the required frequency multipliers and power amplifiers. The average radiated power is approximately 0.5 watt in the 139.1-megacycle frequency range. The transmitter is amplitude modulated by one of five selected tone generators (oscillator) to produce the required homing, left, right, pitch-up, or pitch-down signal: the 2500-cps oscillator for homing, 527-cps oscillator for left turn, 977-cps oscillator for right turn, 1385-cps oscillator for pitch-up, and 1838-cps oscillator for pitch-down.

The carrier is on and power is used whenever the power switch is in the POWER ON position. No standby power or warm up time is required. The homing signal can be overridden at any time by operating command signal switches on the transmitter. It is recommended, however, that "home" be returned to OFF prior to override, if time permits. The transmit antenna is a quarter wavelength vertical.

Ground Handling Equipment

The LUG can be handled on the ground with conventional handling equipment. The LUG may be satisfactorily towed at high speeds on smooth level surfaces by conventional towing vehicles and two tow bars, Ryan Part 180F007-1. (See Figure 15.) The LUG with any load to design capacity may be lifted without special preparation by using a fork lift under the wooden skids, which extend longitudinally under each side of the body. To lift the LUG by helicopter from areas without access roads, it is necessary to remove the flexible wing and support struts, and attach lifting slings to the wing support pads on the LUG body. The LUG may be loaded by hand or with any conventional cargo loading equipment. Two stowable dock boards (Ryan Part 180F004-11, Figure 16) are provided to load vehicular cargo. Fourteen tiedown rings spaced around the body, four on each side and three each front and back, may be used for cargo securing.

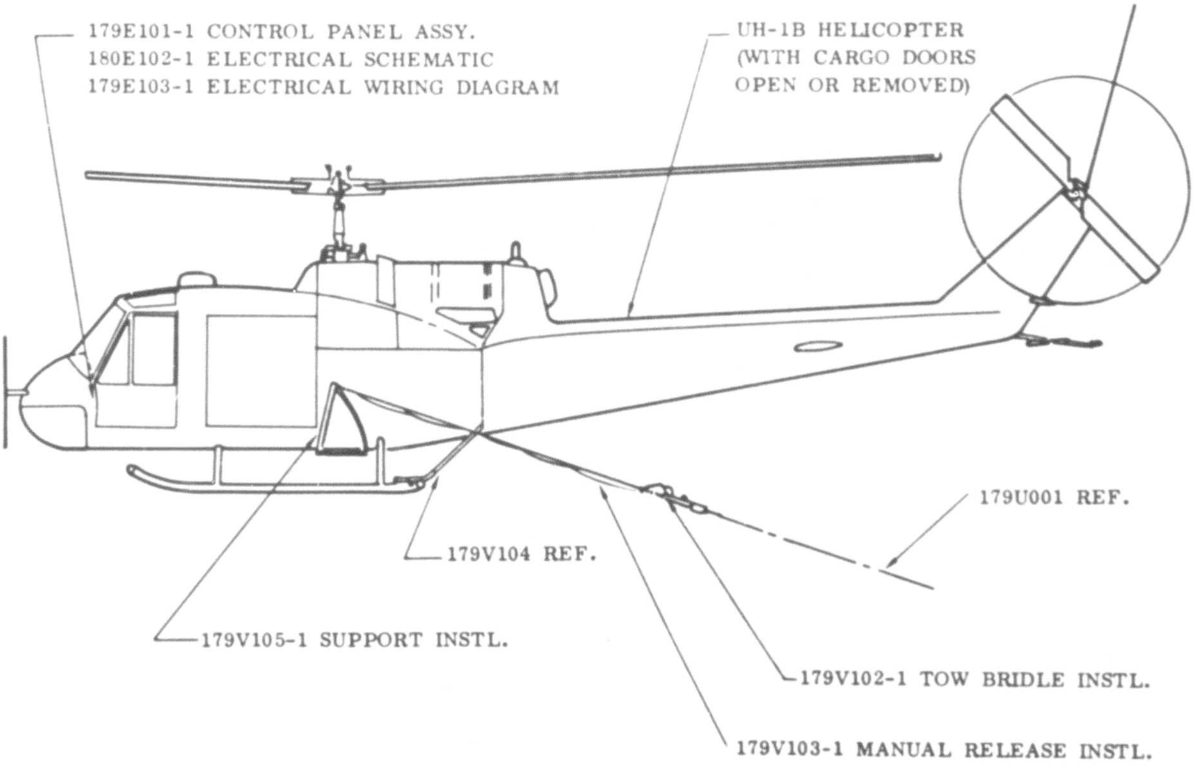


Figure 12. UH-1B Helicopter, Modified to Tow LUG

Figure 13. Radio Control Transmitter

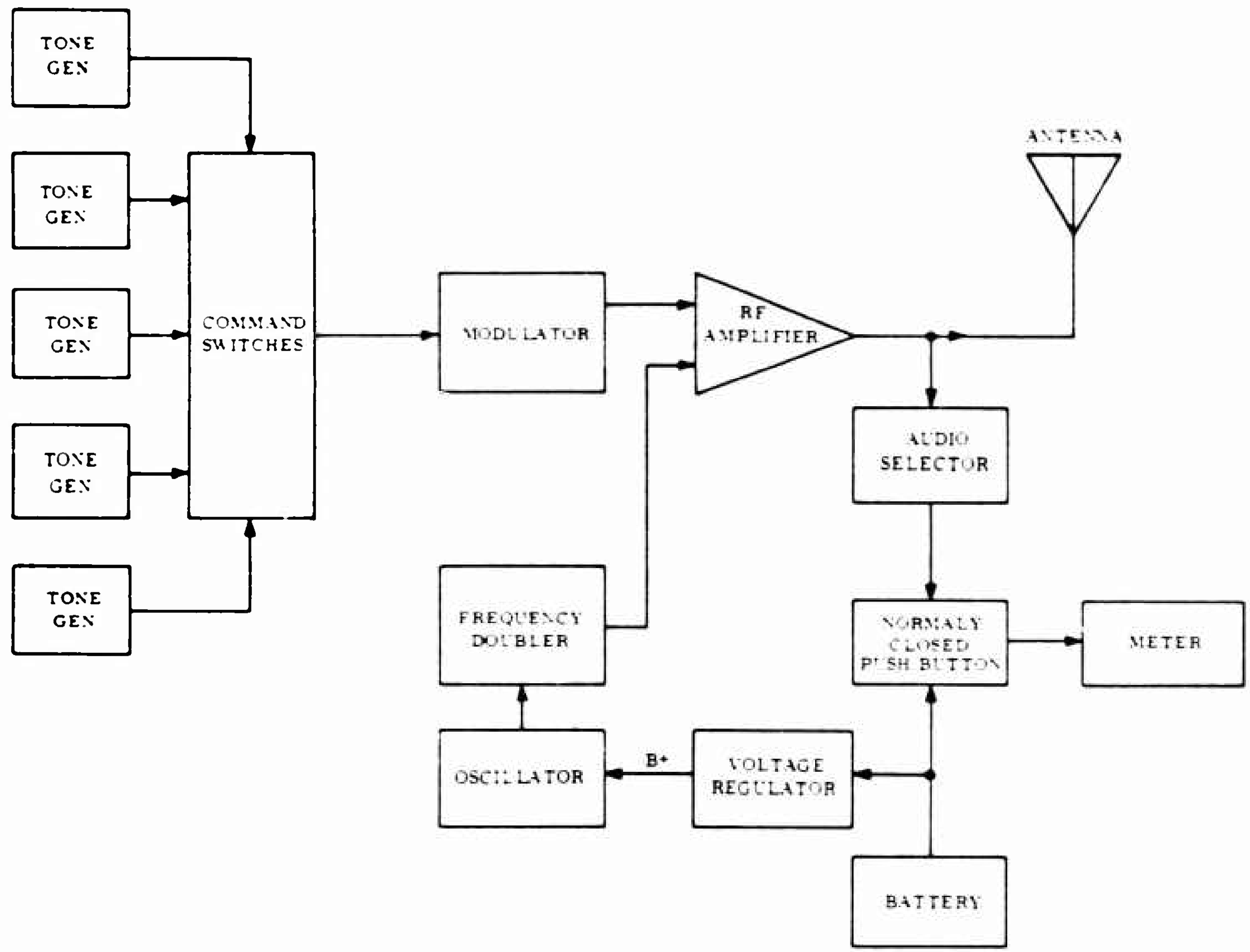


Figure 14. Radio Control Transmitter, Block Diagram

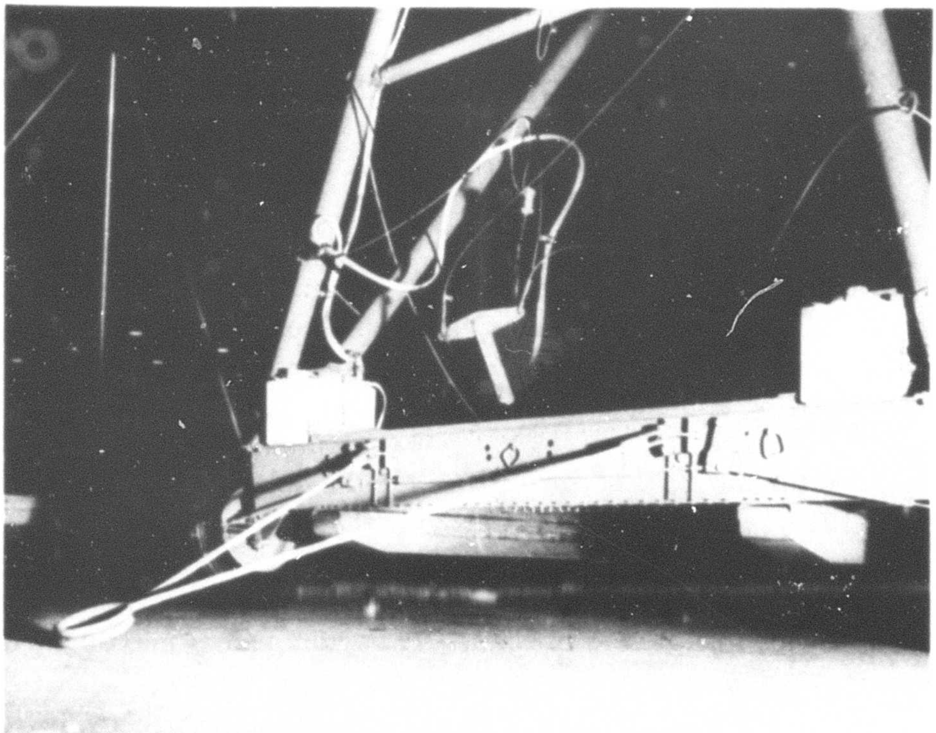


Figure 15. LUG Tow Bars

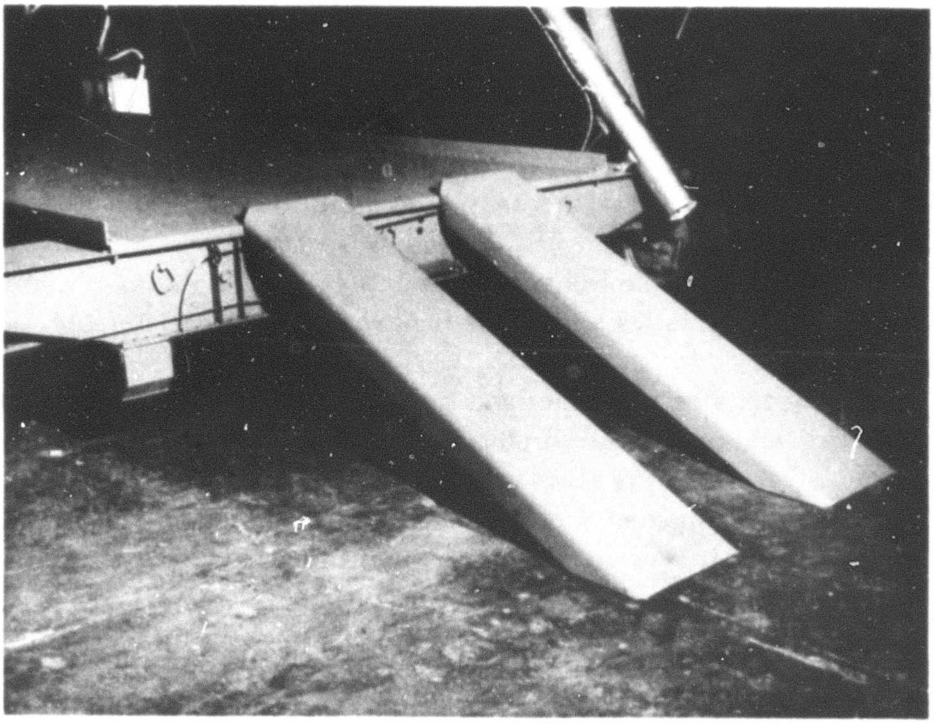


Figure 16. LUG Dock Boards

AERODYNAMICS ANALYSIS

LONGITUDINAL DATA BASIS

The aerodynamic data used as the basis for estimating LUG performance were obtained for the most part from Ryan and NASA-conducted wind tunnel tests. Aerodynamic characteristics of untested components were estimated using standard estimating techniques.

A drag buildup for the LUG at zero lift is tabulated in the following Table I. Drag due to lift was added to C_{D_0} to provide the drag polar presented in Figure 17. The lift curve is shown in Figure 18.

Lift-to-drag ratios are plotted in Figure 19, which shows maximum L/D to be 3.1.

HORSEPOWER REQUIRED AND AVAILABLE

Horsepower required for the UH-1B-LUG combination was determined by first calculating an "equivalent helicopter" and then by solving for power required, using standard helicopter analysis. The "equivalent helicopter" is defined as a helicopter exhibiting the same performance characteristics as the helicopter-plus-glider combination.

The "equivalent helicopter" was determined as follows:

1. Cable tension and cable angle at helicopter were obtained with a tow-cable-characteristics computer program solved by IBM 704.

2. The cable tension was resolved into two components: one in the drag direction and one in the weight direction.

3. The weight component was added to the helicopter gross weight, and the drag component was considered as additional parasite drag.

TABLE I

DRAG BUII DUP

ITEM	f FT.^{2}	ΔC_D
Platform and Sample Cargo	9.95	.0397
Wheels	.731	.0029
Skids	.222	.00088
Springs	.667	.0027
Control Box & Flare Switch	.562	.00224
Tow Line Attach Cables	.0973	.00038
Actuator	1.094	.0044
Roll Cables	.385	.00153
Cross Tube	.569	.00226
Wing-Body Struts	11.05	.0441
Vertical Tail	.0966	.00038
Sub Total	25.423	.1014
Misc. (5% of Sub Total)	1.271	.0051
Wing	20.064	.0800
	46.758	.1865

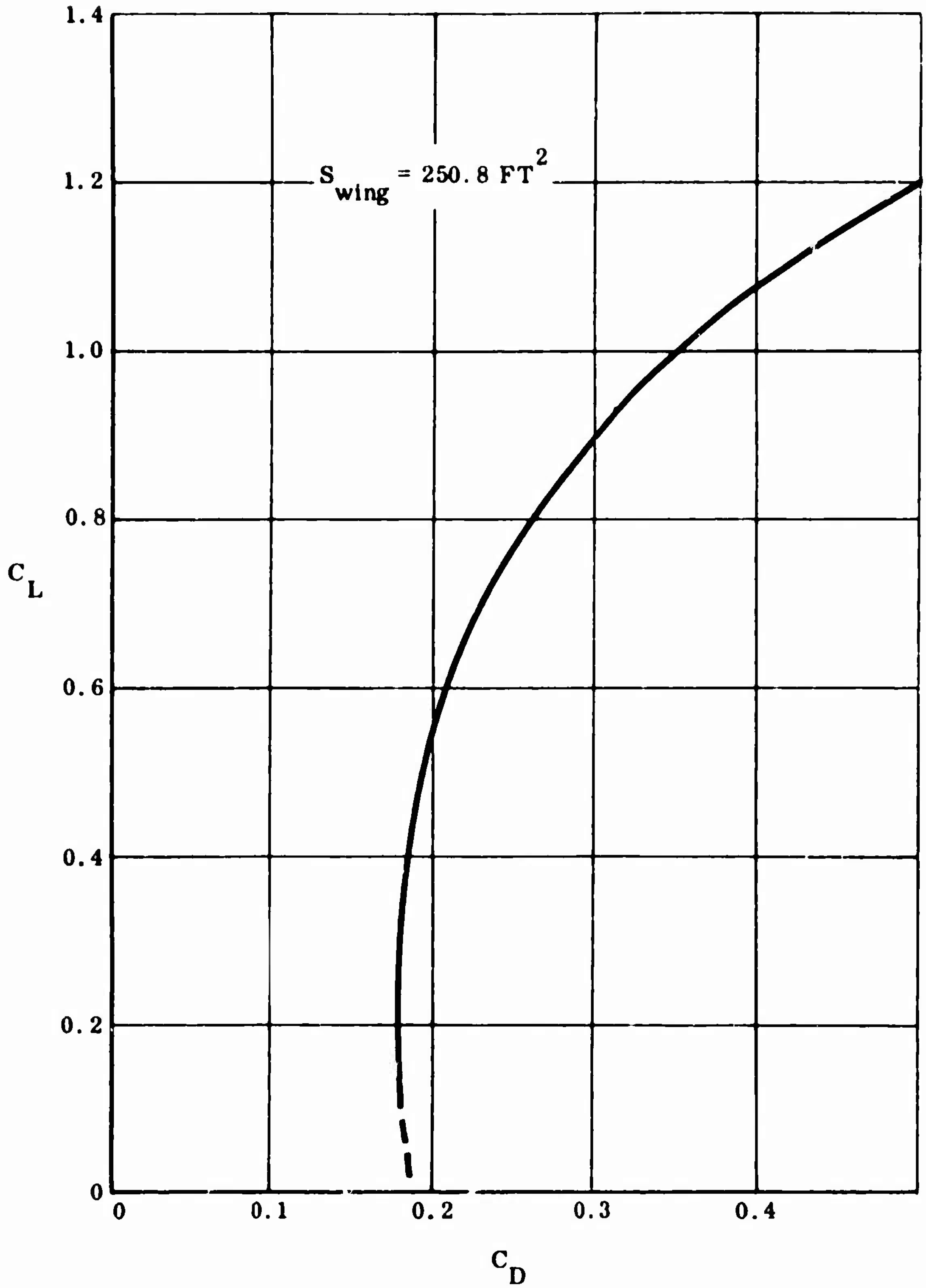


Figure 17. Drag Polar

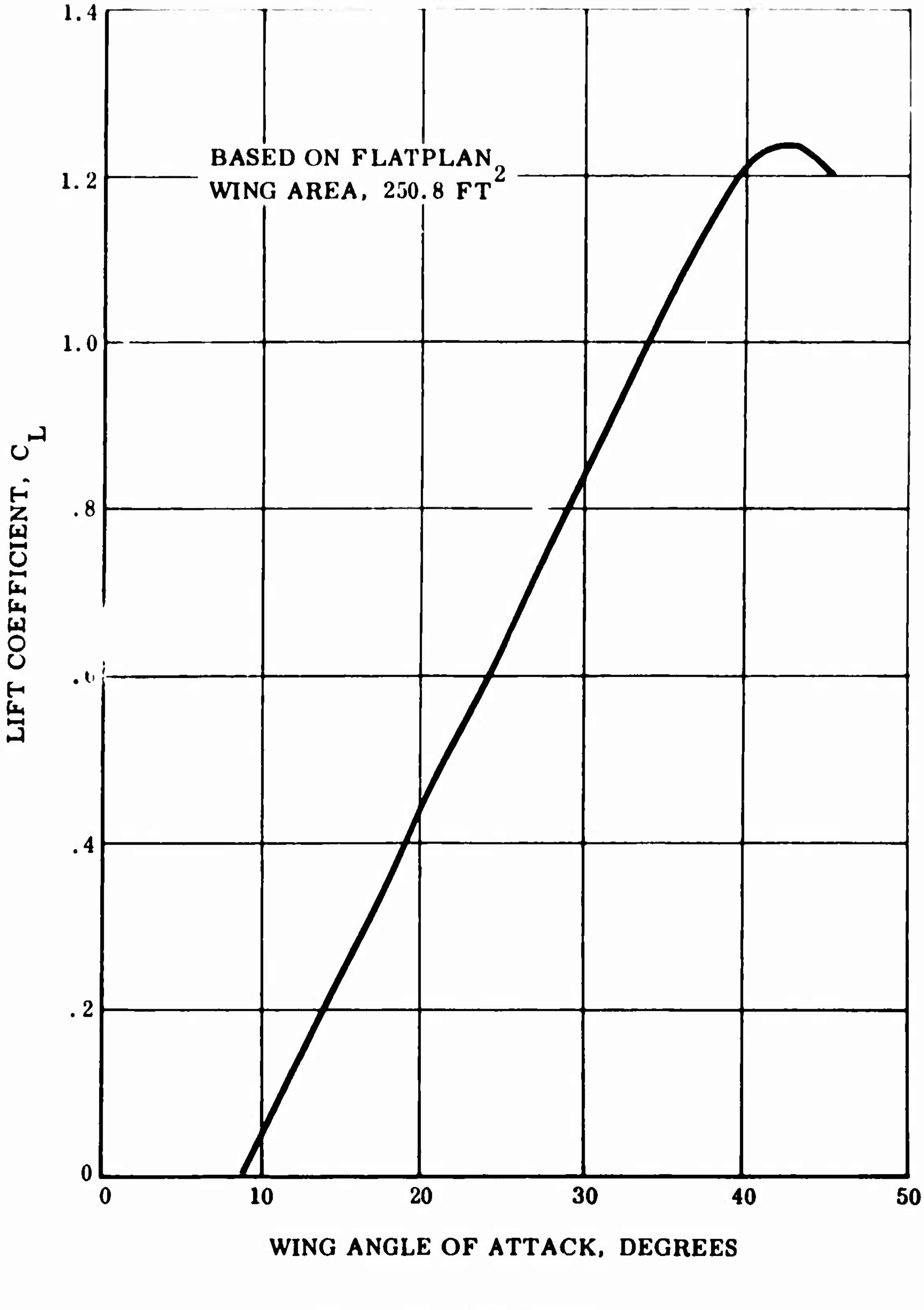


Figure 18. Lift Curve

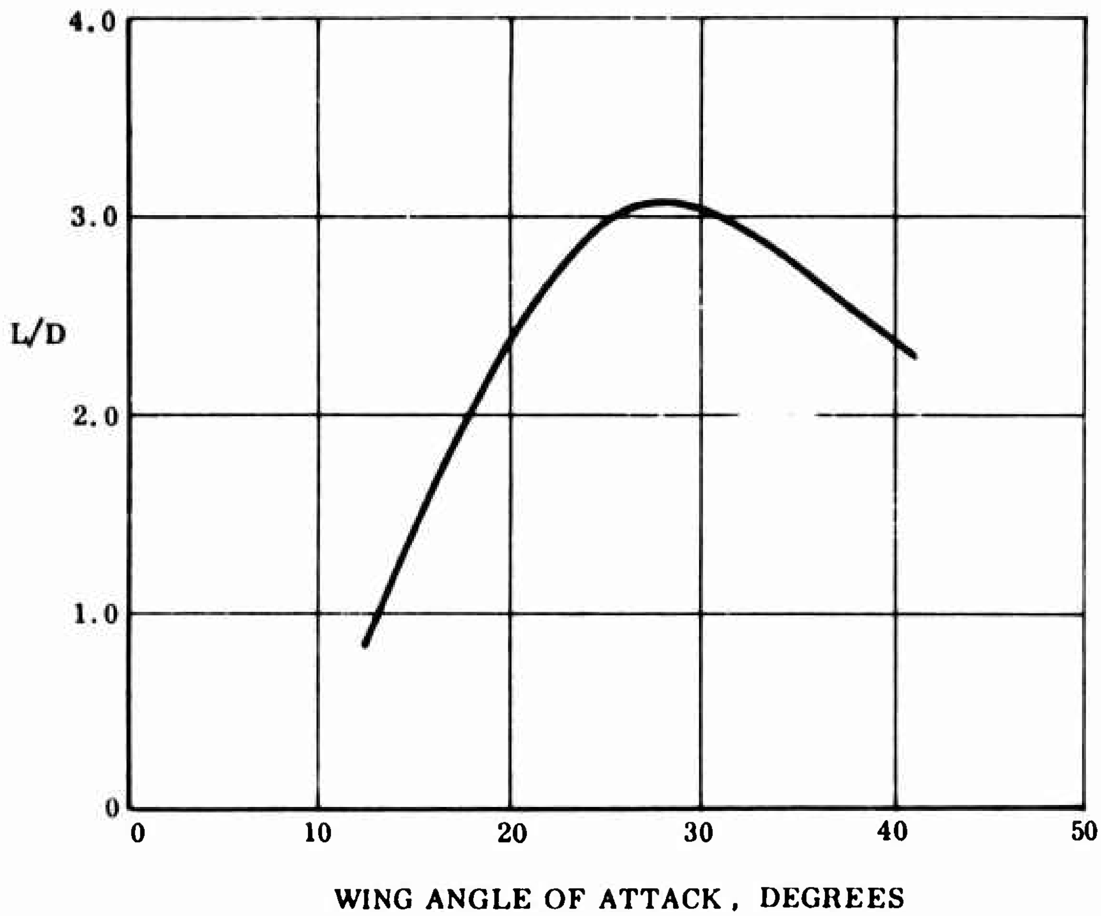
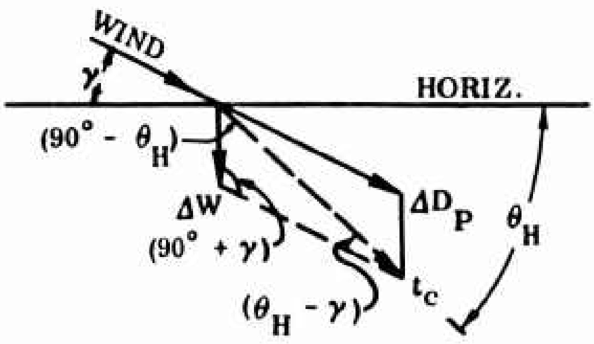


Figure 19. Lift-to-Drag Ratios

The tension components were resolved using the following force diagram:



$$\frac{t_c}{\text{Sin }(90 + \gamma)} = \frac{\Delta W}{\text{Sin }(\theta_H - \gamma)} = \frac{\Delta D_P}{\text{Sin }(90 - \theta_H)}$$

$$\Delta W = \frac{t_c \sin(\theta_H - \gamma)}{\sin(90^\circ + \gamma)}$$

$$\Delta D_P = \frac{t_c \sin(90^\circ - \theta_H)}{\sin(90^\circ + \gamma)} = \frac{t_c \cos\theta_H}{\sin(90^\circ + \gamma)}$$

where,

γ = flight path angle

θ_H = cable angle below horizontal

t_c = cable tension

ΔW = weight component of cable tension

ΔD_P = parasite drag component of cable tension.

For level flight, $\gamma = 0$ and the expressions for ΔW and ΔD_P reduce to:

$$\Delta W = t_c \sin \theta_H$$

$$\Delta D_P = t_c \cos \theta_H$$

The total power required at the helicopter rotor shaft for the UH-1B-glider combination was calculated by IBM 704 utilizing the computation methods of References 1 and 2. The digital program does not use small angle assumptions regarding blade section inflow angles and velocities. Allowance is made for stall in the reversed-flow region.

The calculated power required does not include power losses due to transmission, cooling, antitorque, etc. These losses are accounted for in the power available which is reduced 10% for this purpose. Figures 20 and 21 present power required and available for the UH-1B plus LUG for sea level and 5,000 feet respectively. The engine assumed for the UH-1B is the Lycoming T-53-L-9 rated at 1100 horsepower at sea level.

MAXIMUM TOW SPEEDS

Power-limited maximum speeds were obtained from the intersection of the power required and power available curves. Maximum speed at sea level with 1,000 pounds of payload is 83.0 knots.

RATES OF CLIMB

Rates of climb were calculated using the equation

$$R/C = \frac{(\text{H. P. avail.} - \text{H. P. req.})\ (33{,}000)}{\text{Weight}_{(\text{Helicopter + Glider})}}$$

Horsepower required and horsepower available are for the equivalent helicopter and were obtained from Figures 20 and 21.

The results are plotted in Figure 22 which shows the maximum rate of climb to be 2040 and 1710 at sea level and 5,000 feet respectively.

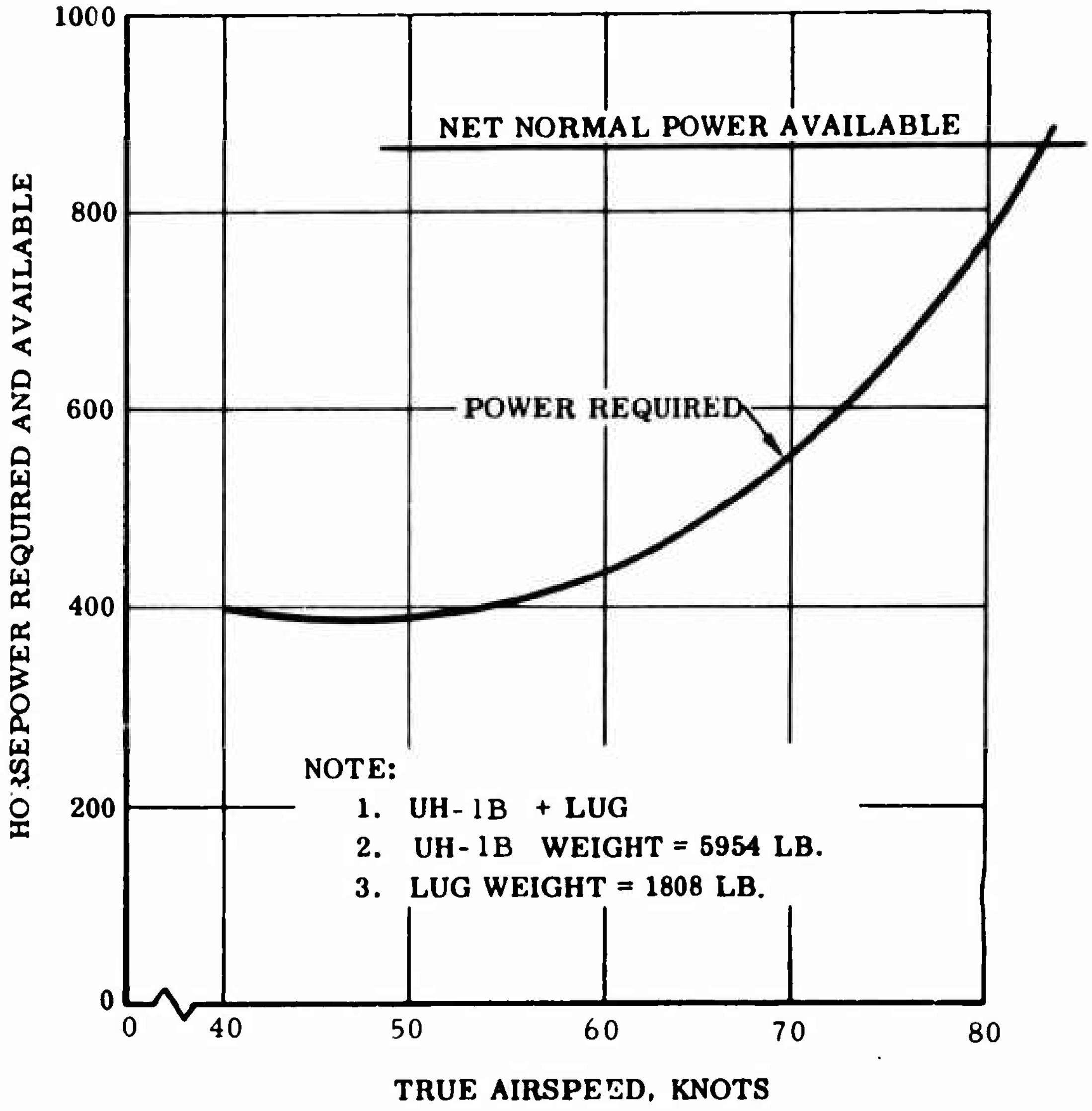


Figure 20. Horsepower Required and Available at Sea Level

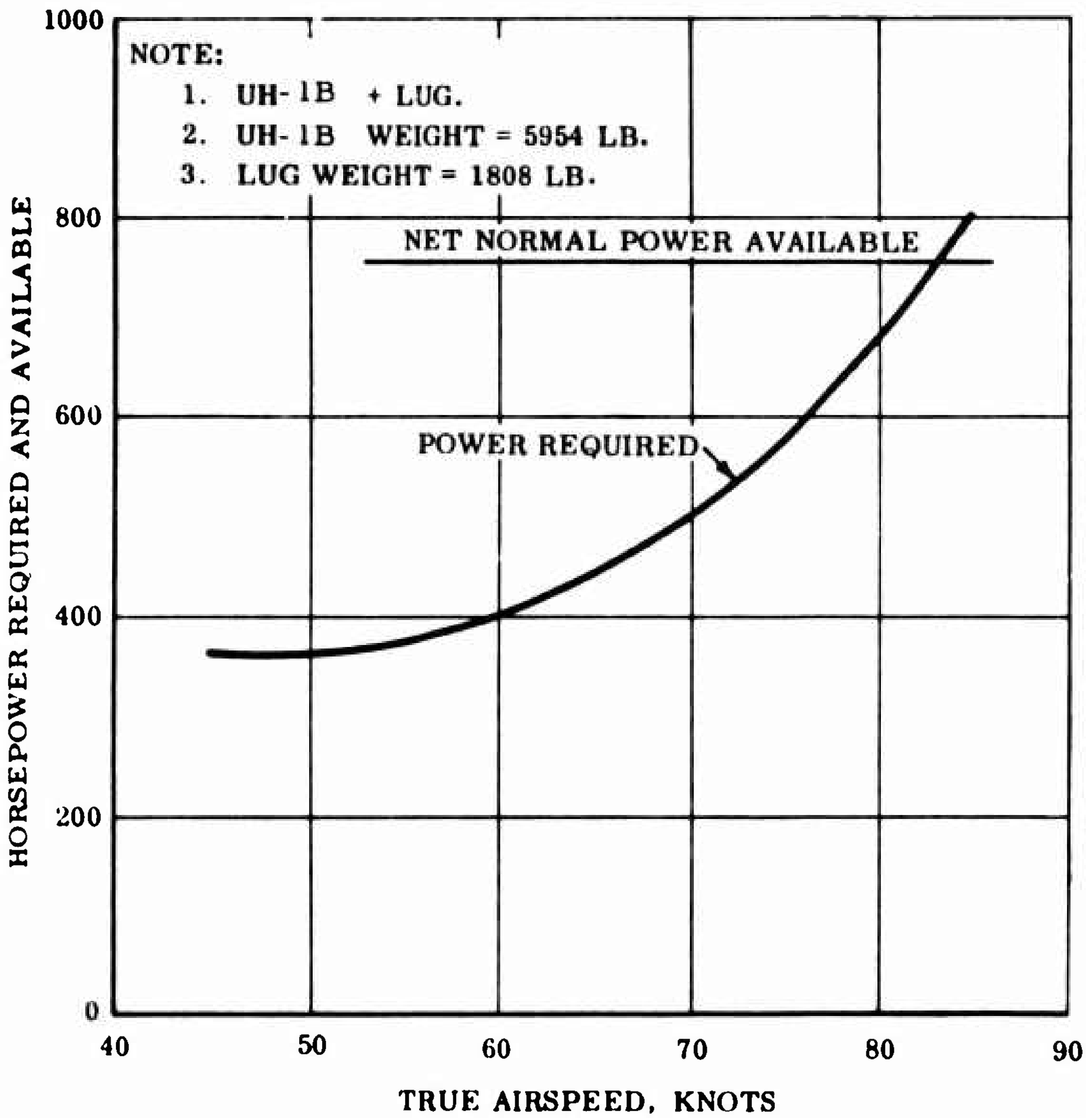


Figure 21. Horsepower Required and Available at 5,000-foot Altitude

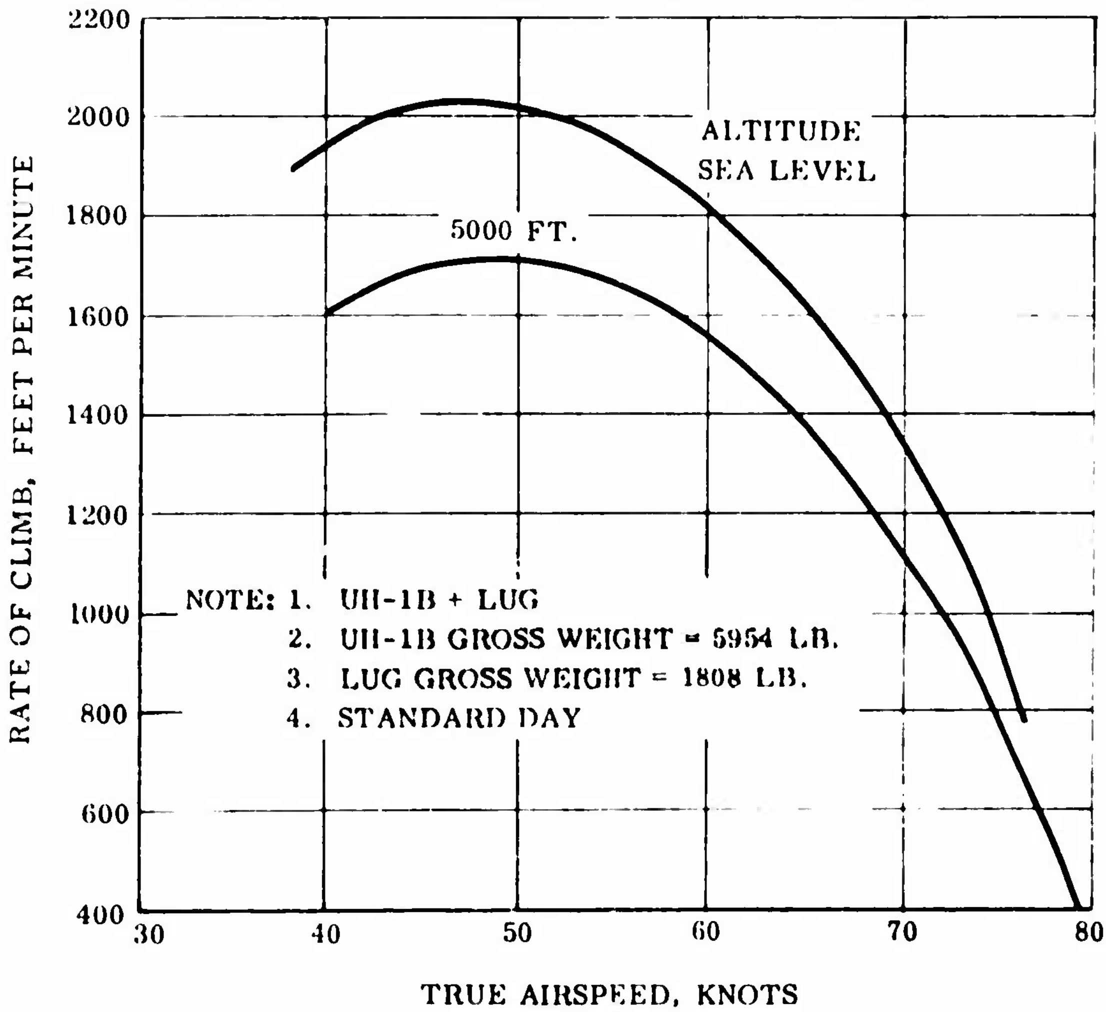
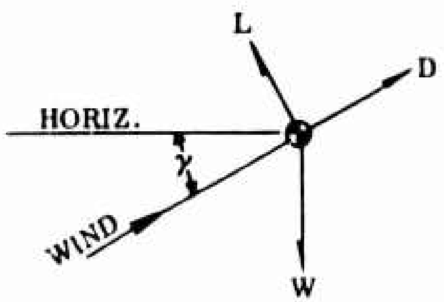


Figure 22. Rate of Climb

GLIDE PERFORMANCE

Still-air glide range is plotted in Figure 23 as a function of altitude and speed. Maximum range, attained at maximum L/D, provides a glide ratio of 3.1 to 1. Speed for maximum range is 51 knots. Rates of descent and glide velocities at sea level are presented in Figures 24 and 25 respectively. Glide performance was determined as follows:

Consider the following force diagram representing gliding flight:



where,

L = lift

D = drag

W = weight

γ = flight path angle

Summing forces in the lift and drag directions gives:

$$L - W \cos \gamma = 0$$

$$D - W \sin \gamma = 0 \text{ and,}$$

$$L = W \cos \gamma$$

$$D = W \sin\gamma$$

$$L/D = W \cos\gamma / W \sin\gamma$$

$$\gamma = \cot^{-1} (L/_D)$$

$$L = C_L \, 1/2 \, \rho \, V^2 S = W \cos\gamma$$

$$V_{glide} = \sqrt{\frac{2 \, W \cos\gamma}{C_L \, \rho \, S}}$$

$$\text{rate of descent} = V_{glide} (\sin\gamma)$$

$$\text{glide range} = \text{start of glide altitude}/\tan\gamma$$

TAKEOFF

An expression for takeoff ground run was derived as follows:

$$a = \frac{d\,V}{d\,t} = \frac{d\,V}{d\,s}\frac{d\,s}{d\,t} = \frac{v\,d\,V}{d\,s}$$

$$V\,dV = \frac{d\,V^2}{2}$$

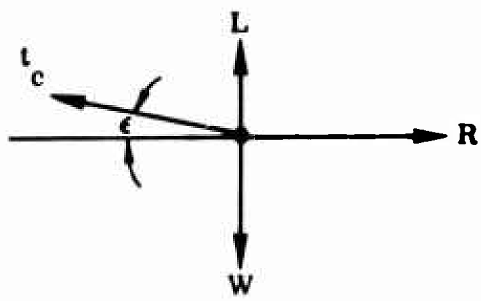
$$a = \frac{d\,V^2}{2\,d\,s}$$

$$d\,s = \frac{d\,V^2}{2\,a}$$

$$s = \frac{1}{2} \int_{o}^{V_{LD}} \frac{d\,V^2}{a}$$

The above equation was solved graphically by plotting the magnitudes of 1/2 a as ordinates against V^2 as abscissas. The takeoff distance is then equal to the area under the curve for the interval $V^2 = 0$ to $V^2 = V^2_{LO}$. Acceleration was determined as follows:

Consider the following force diagram representing the glider forces,



$$a = \frac{t_c \cos \epsilon - R}{m}$$

where

t_c = cable tension at glider, pounds

ϵ = cable angle, degrees

m = mass of glider, slugs

L = lift, pounds

W = weight of glider, pounds

R = resistance = $D + \mu \, (W - L - t_c \sin \epsilon)$

D = drag, pounds

μ = coefficient of rolling friction = 0.025

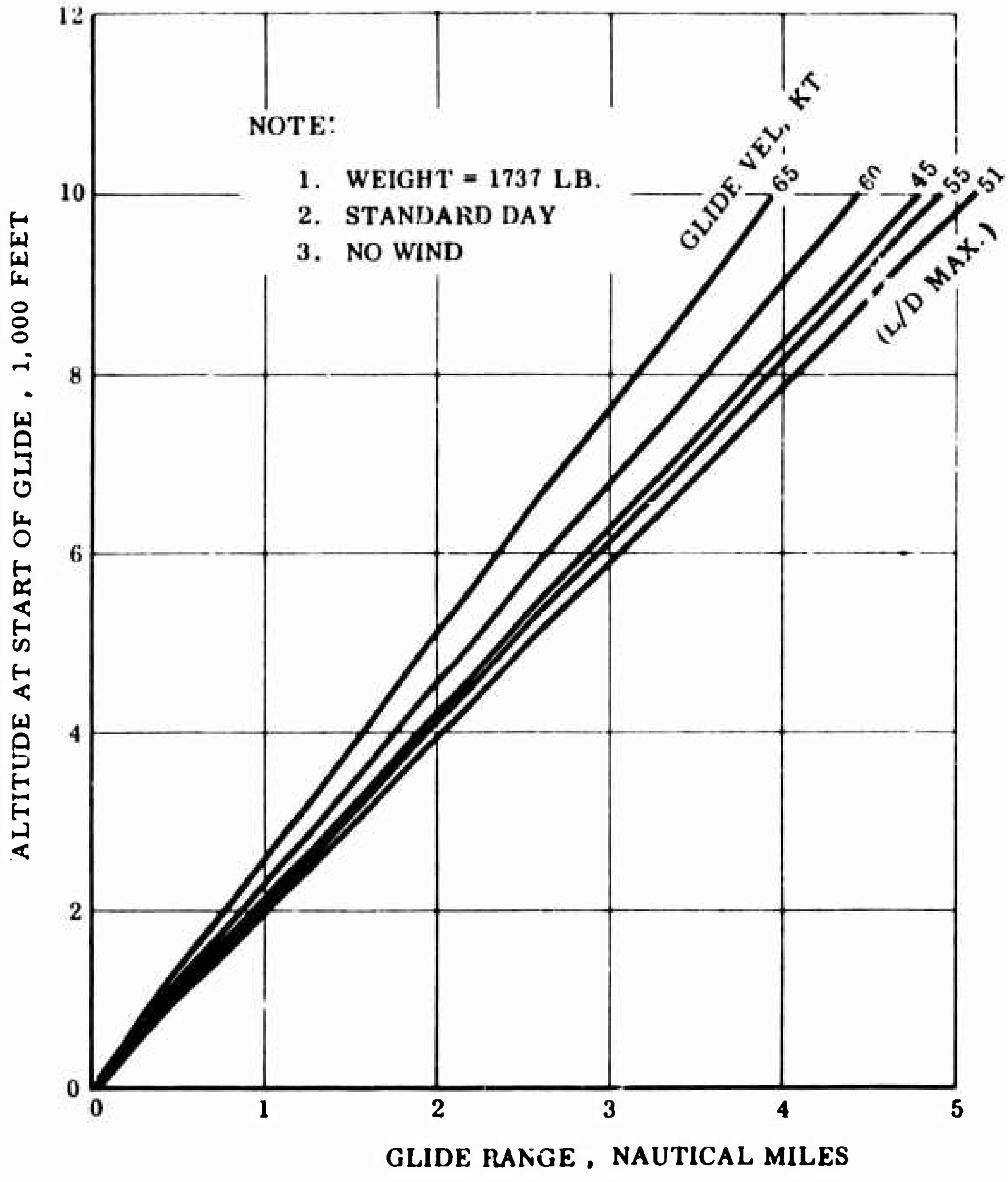


Figure 23. Glide Range

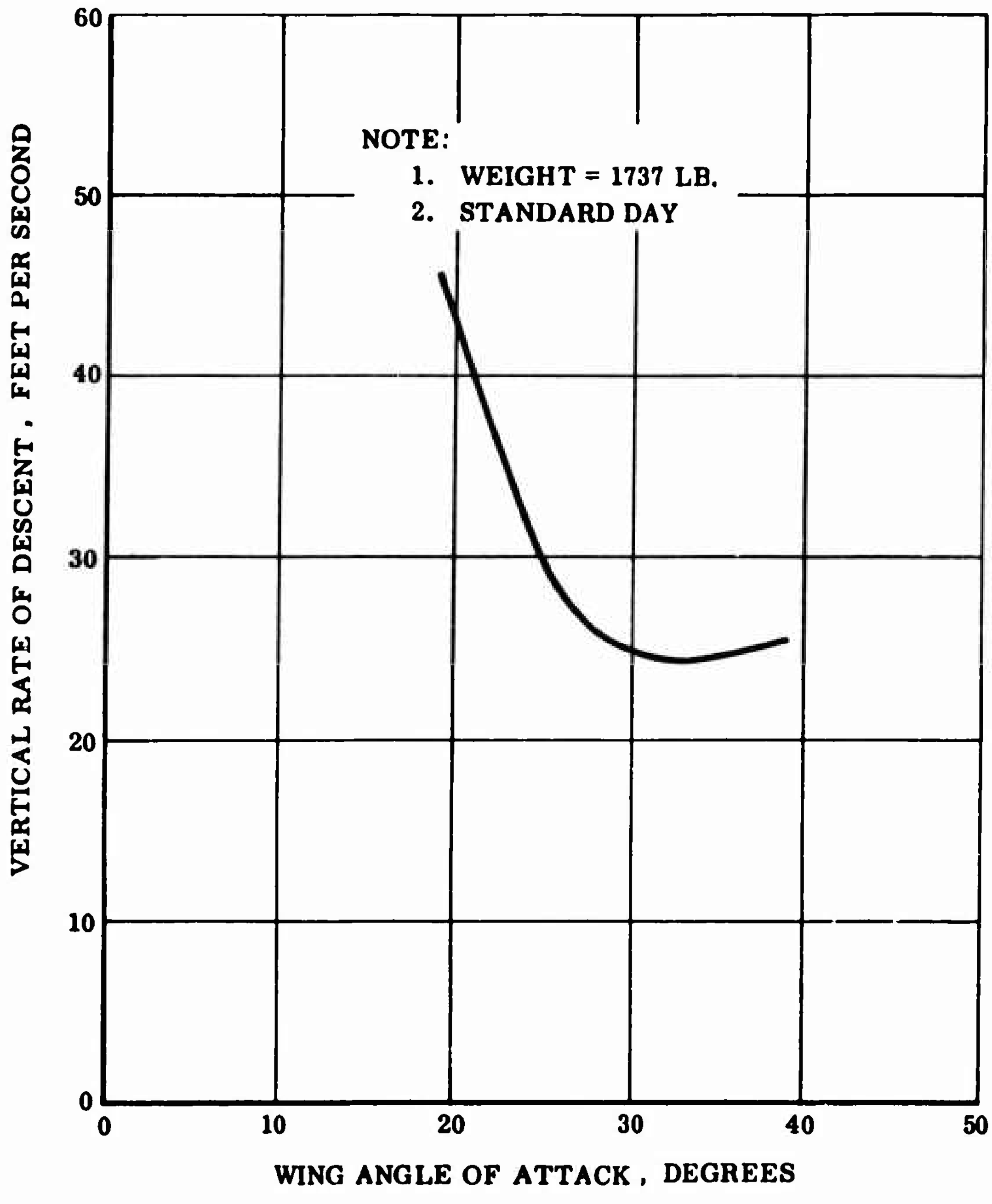


Figure 24. Rate of Descent at Sea Level

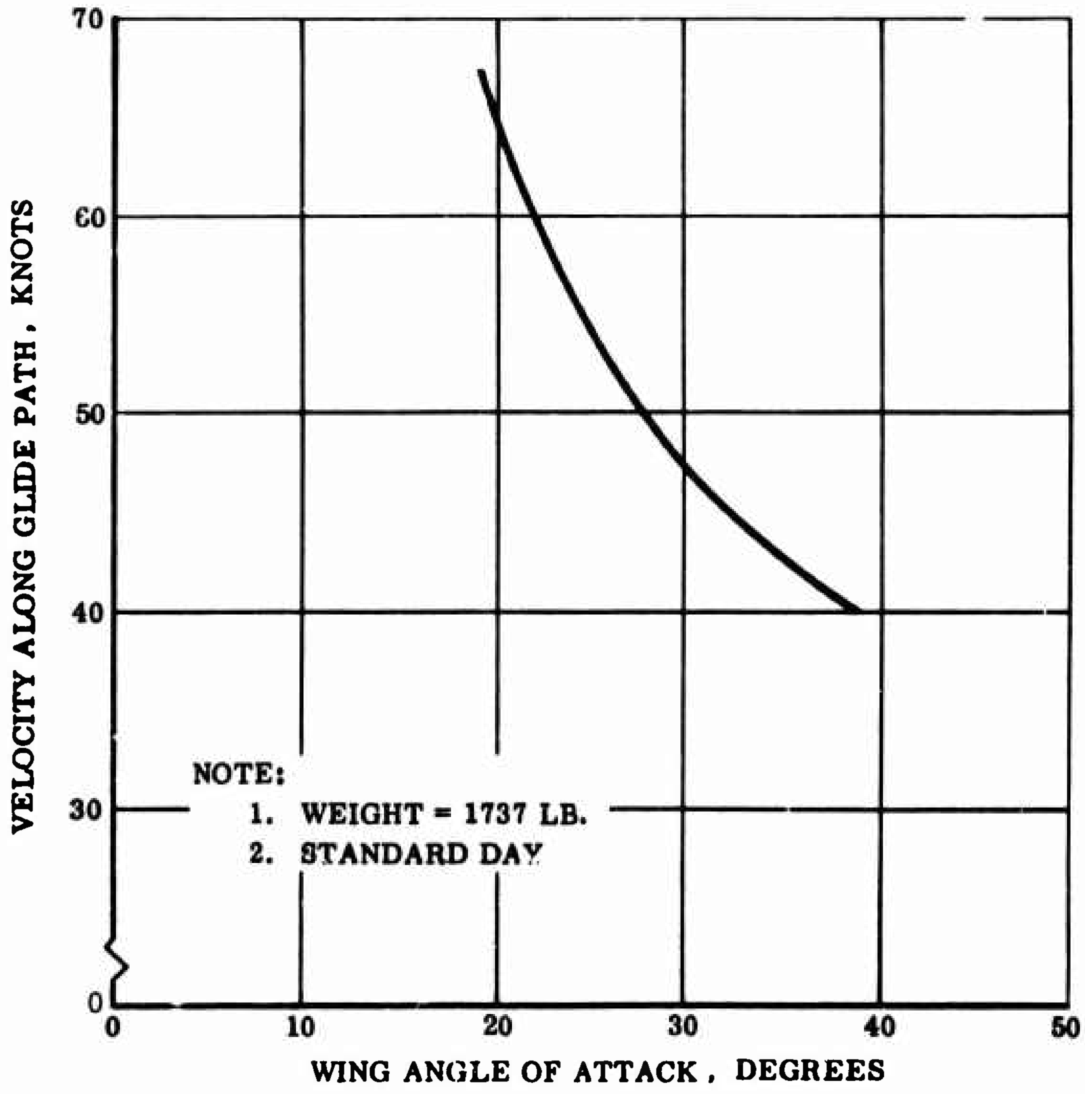


Figure 25. Glide Velocity at Sea Level

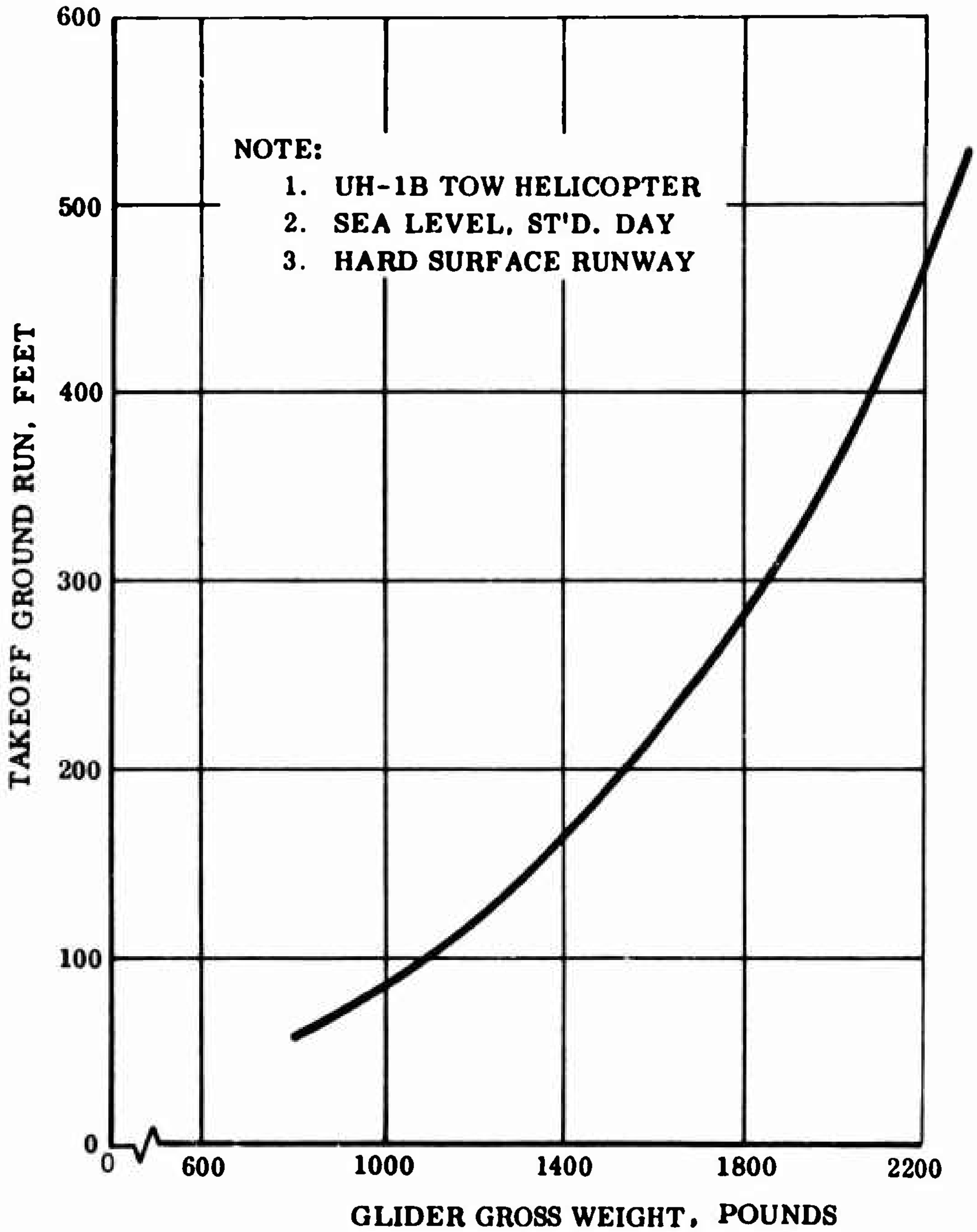


Figure 26. Takeoff Performance

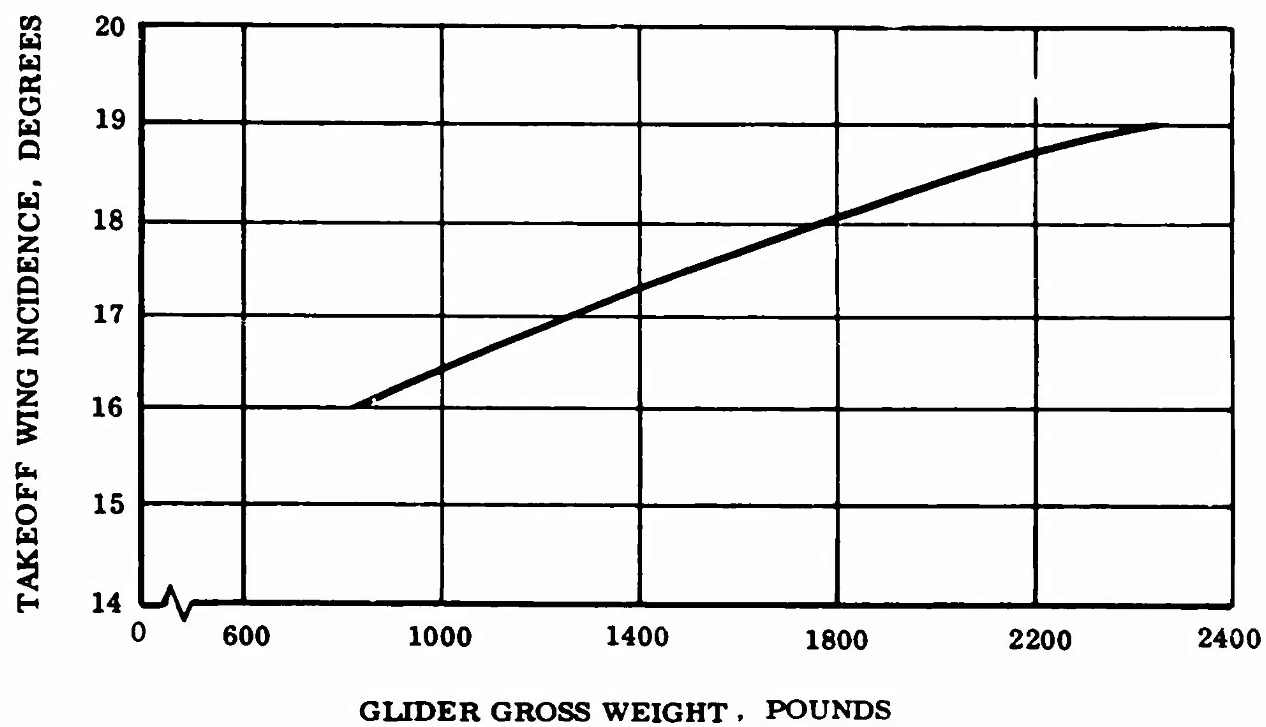


Figure 27. Takeoff Wing Settings

LANDING

The landing ground roll was calculated from the following equation obtained from Reference 5,

$$S_L = \frac{0.1022\ V^2}{\mu_\beta - (D/L)} \log_{10} [\mu_\beta (L/D)]$$

where

S_L = landing ground roll, feet

V = touchdown velocity, knots

μ_β = braking coefficient = 0.4

L = lift at touchdown, pounds

D = drag at touchdown, pounds

The maximum roll distance occurs when the entire ground run is accomplished with the skids off the ground. Figure 28 presents roll distances for this condition showing the ground roll to be 388 feet at the maximum gross weight of 2308 pounds. Touchdown velocity is 1.2 V_{stall}.

STALL SPEEDS

Glider stall speeds for free flight were calculated using the following equation:

$$V_S = \sqrt{\frac{W.\ (295)}{C_L \max \sigma S}}$$

The results are plotted in Figure 29 showing stall speeds to be 28 knots and 47.5 knots at empty weight (808 pounds) and maximum weight (2308 pounds) respectively.

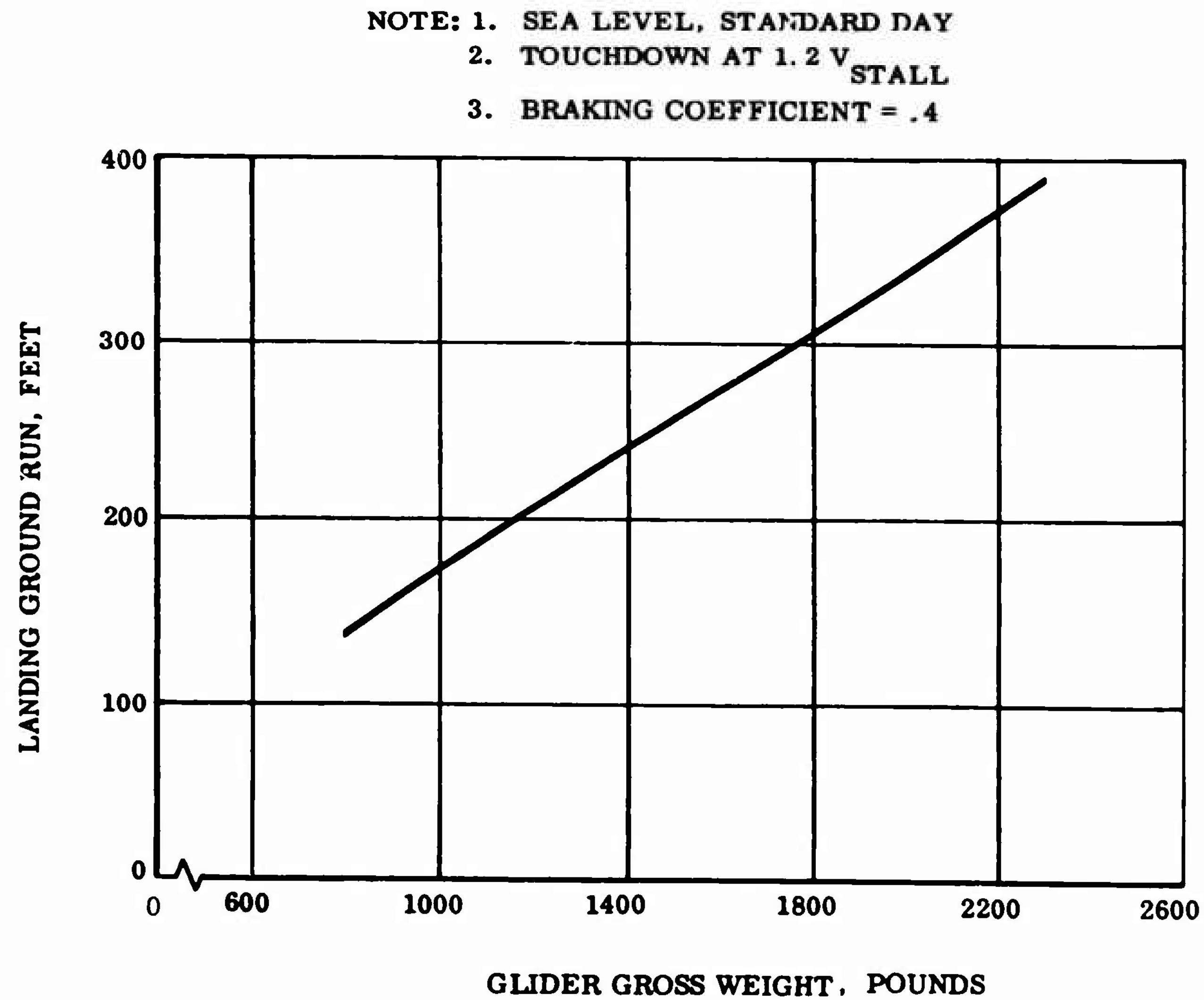


Figure 28. Landing Performance

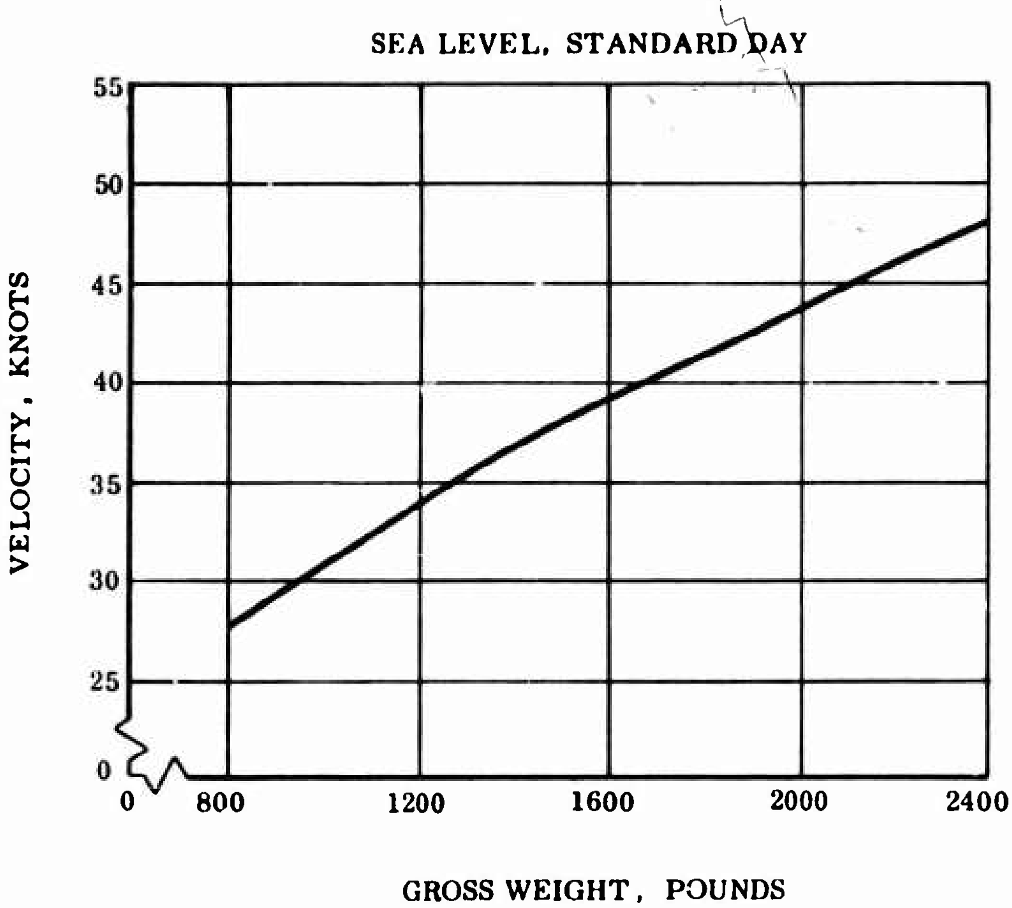


Figure 29. Stall Speeds

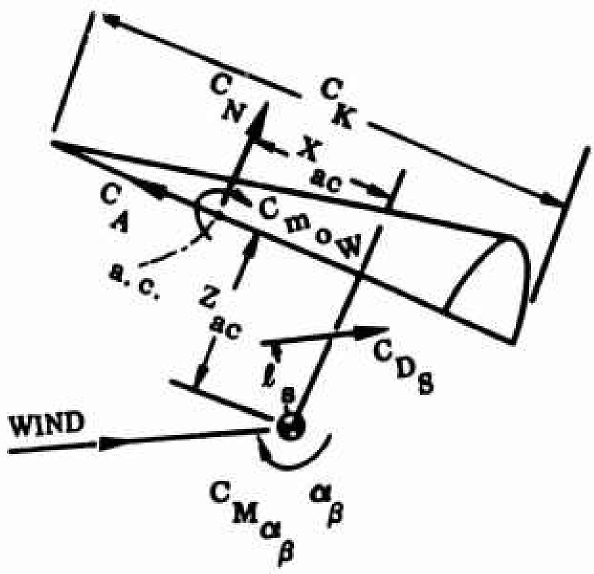
LONGITUDINAL TRIM

Longitudinal trim analyses have been performed for both on-tow and 1-g gliding flight conditions.

Pitching moment coefficients for gliding flight were calculated as functions of angle of attack and wing-body incidence from the following equation for pitching moment coefficient about the glider's center of gravity.

$$C_{m_{cg}} = C_N \left(\frac{Xac}{C_K}\right) + C_A \left(\frac{Zac}{C_K}\right) + C_{m_{o_W}} + CD_S \left(\frac{\ell s}{C_K}\right) + C_{m_{\alpha_\beta}} \alpha_\beta$$

The symbols in the following diagram are defined in the List of Symbols.



X ac and Z ac are functions of wing incidence as shown in Figure 30. The wing normal-force and axial-force coefficients C_N and C_A are plotted versus angle of attack in Figure 31.

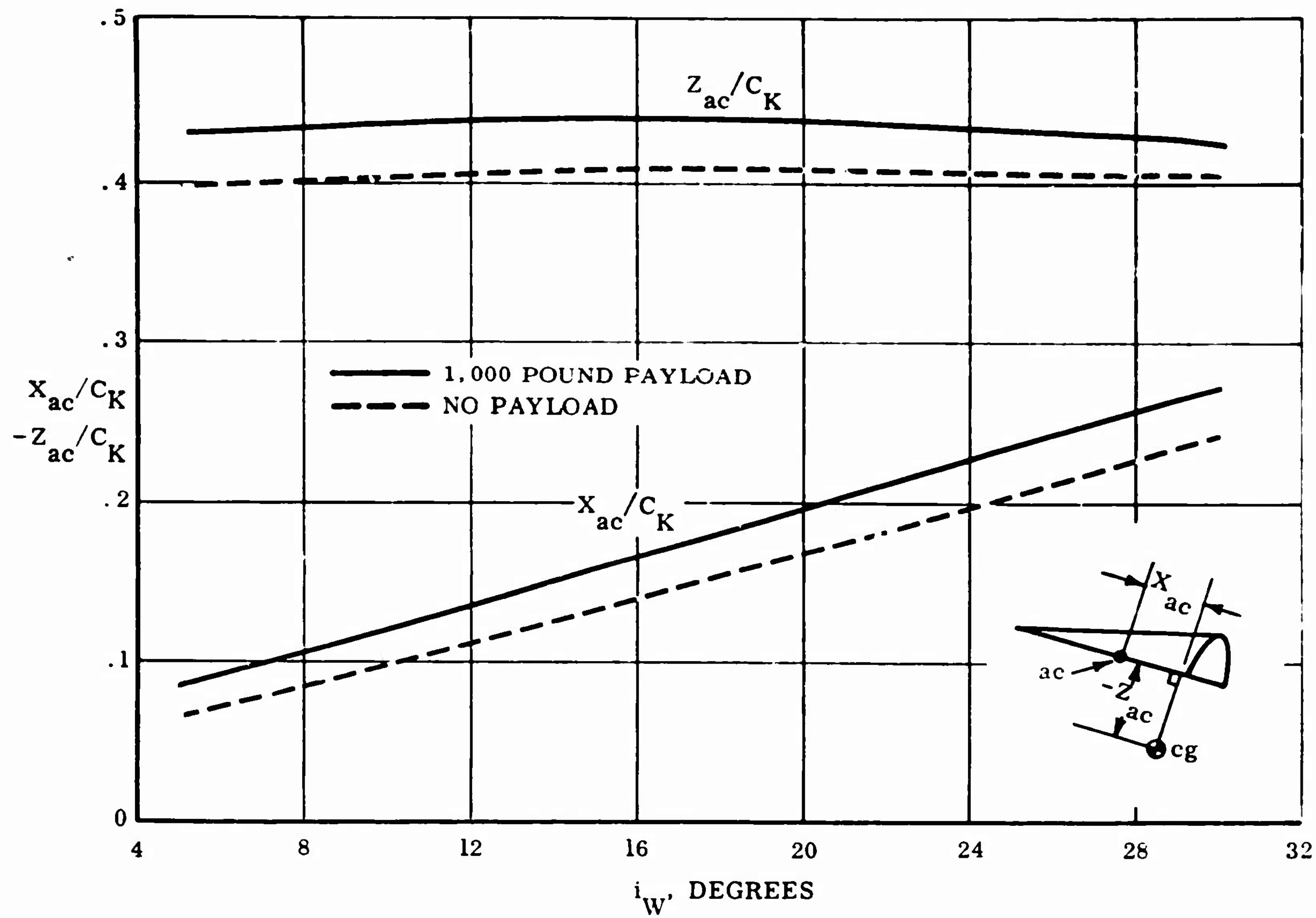


Figure 30. Center-of-Gravity Positions

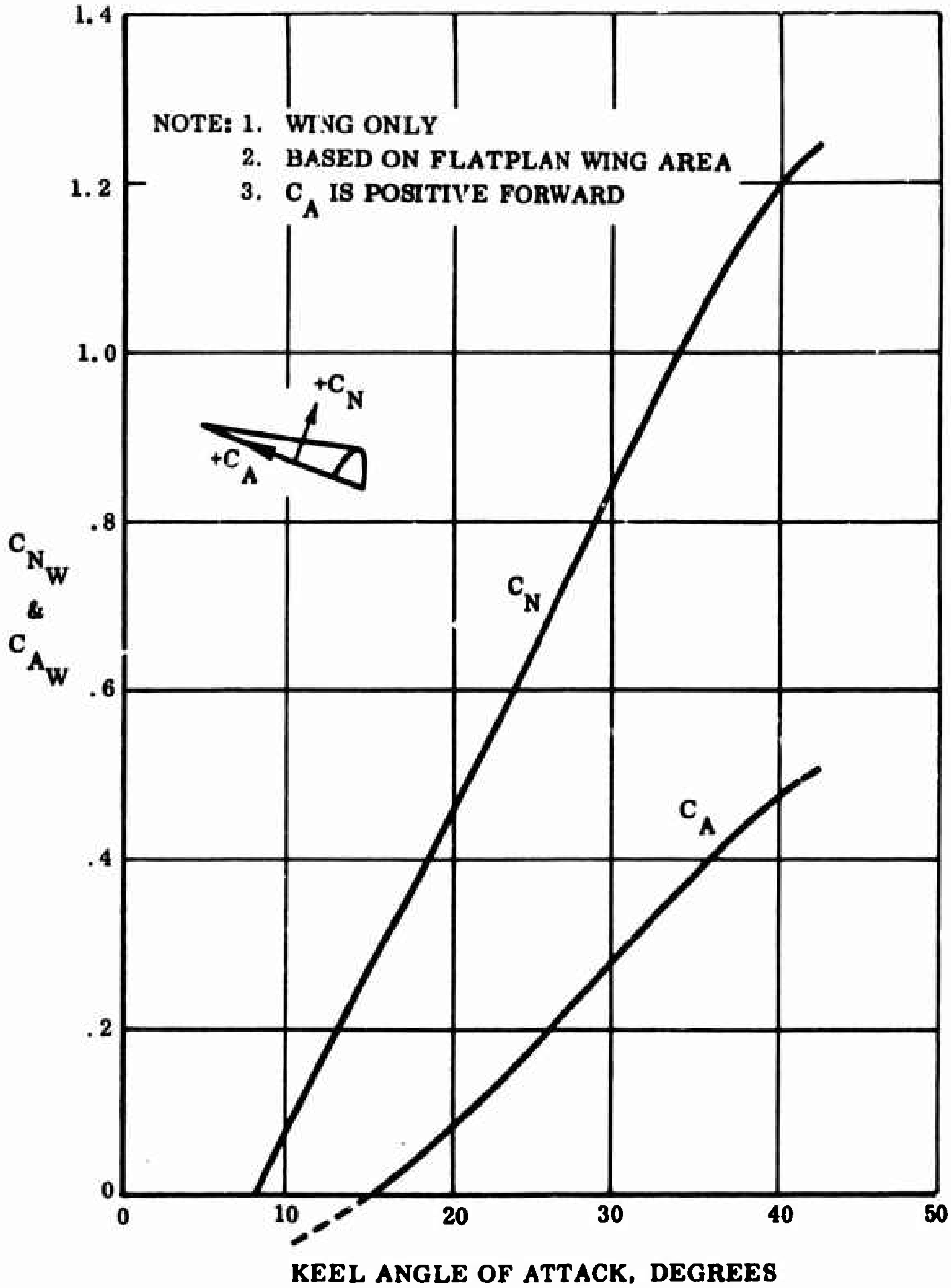


Figure 31. Flex Wing Normal and Axial Force

Example $C_{m_{CG}}$ versus α curves are presented in Figure 32 for off-tow conditions. Trim angles of attack were read at the point of zero pitching moment to provide the curve of wing incidence vs. trim angle of attack presented in Figure 33.

Trim airspeeds were calculated for off-tow 1-g gliding flight as follows:

$$V_{trim} = \sqrt{\frac{W\ (295)}{C_{L_{trim}}\ \sigma S}}$$

where,

V_{trim} = trim velocity, knots

W = gross weight, pounds

C_L = lift coefficient

S_W = wing reference area, 250.8 square feet

The results are presented in Figure 34 as curves of trim airspeed versus wing angle of attack.

Curves of wing incidence versus trim airspeed in free flight are presented in Figure 35 for three gross weights at sea level, standard day conditions. Values for Figure 35 were obtained from Figures 33 and 34.

On-tow trim was calculated by means of a digital computer program which includes the effects of tow-cable tension on lift, drag, and pitching moment. The equations of motion used and a description of the program may be found in Reference 5.

Data obtained from the computer include vertical separation between the glider and helicopter, tow-cable angles, cable tension, and trim wing incidence. These data are presented in Figures 36 through 40.

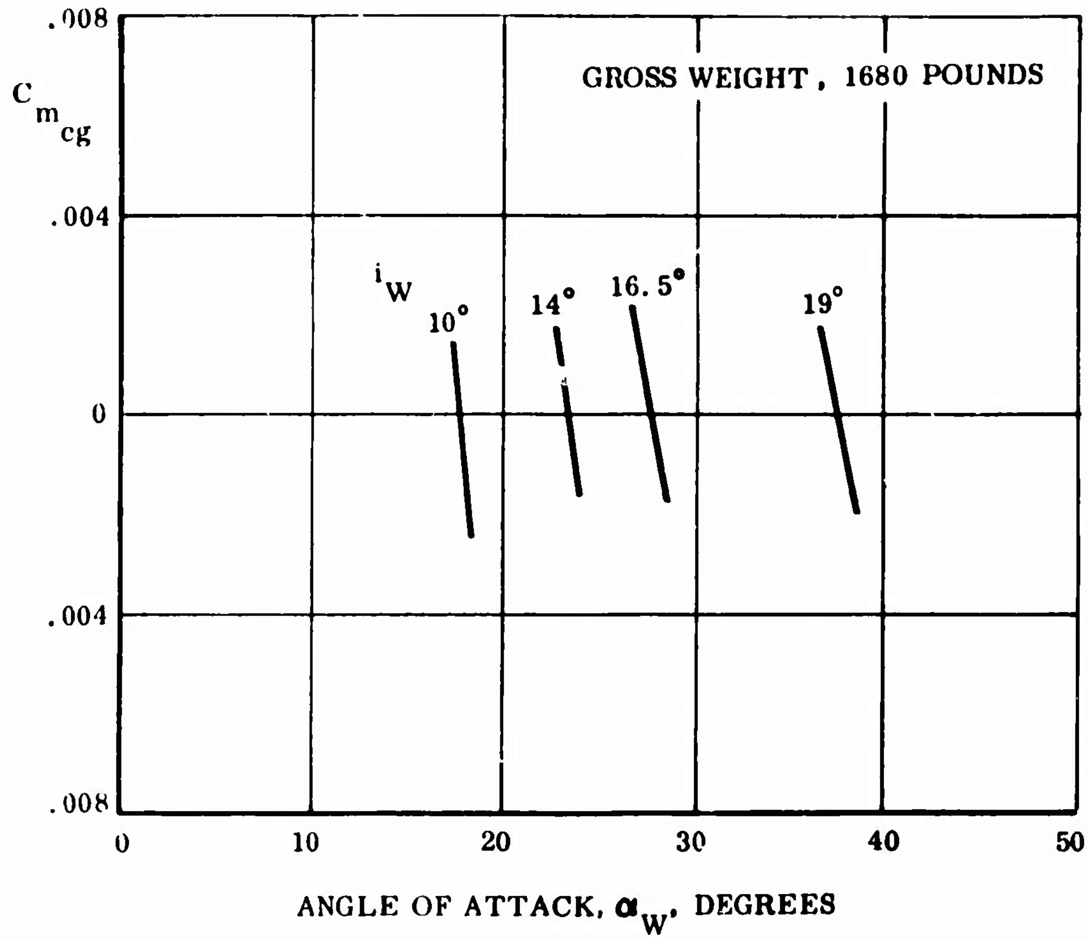


Figure 32. Pitching Moment Coefficient About Center-of-Gravity

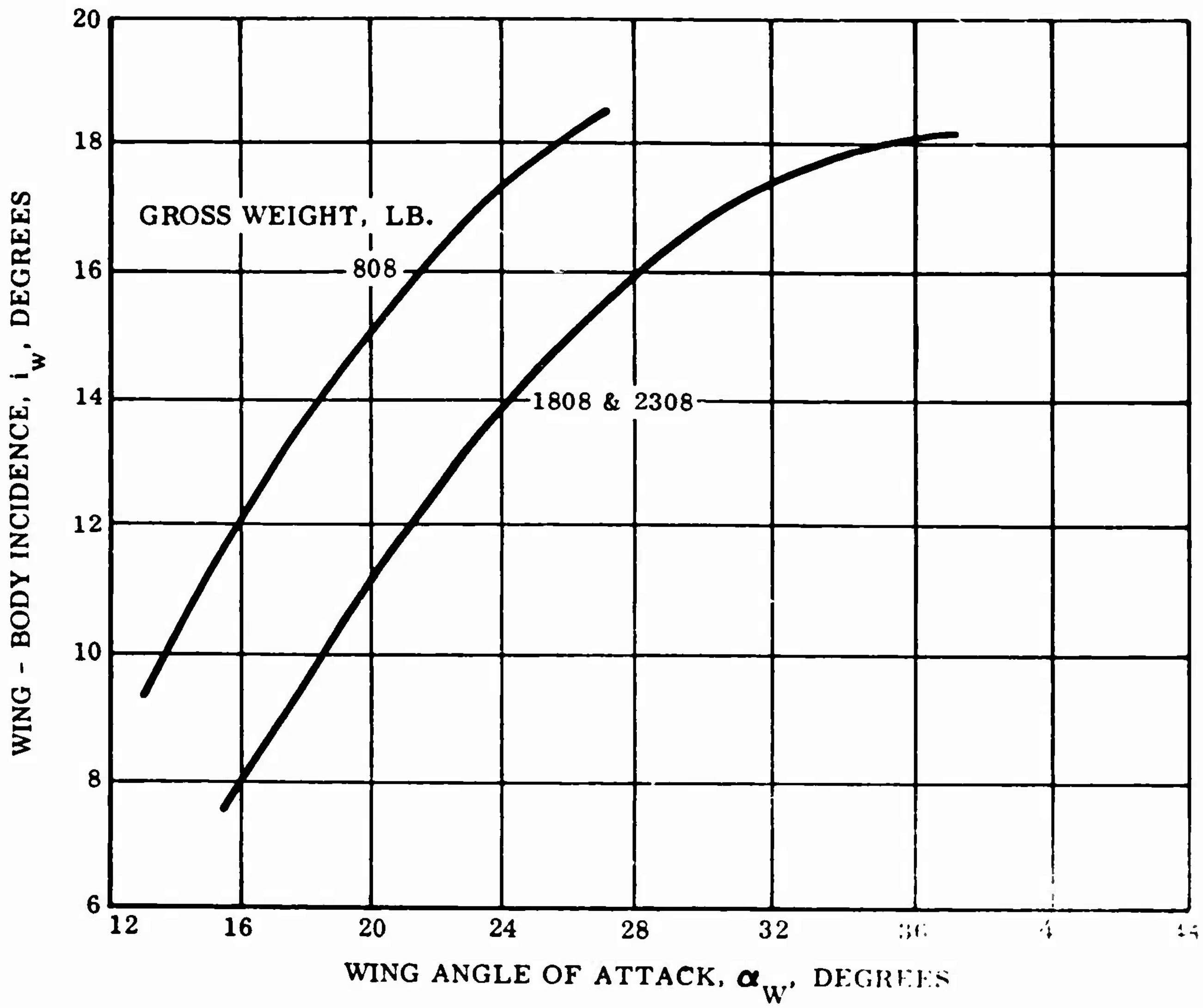


Figure 33. Wing-Body Incidence Versus Wing Angle of Attack

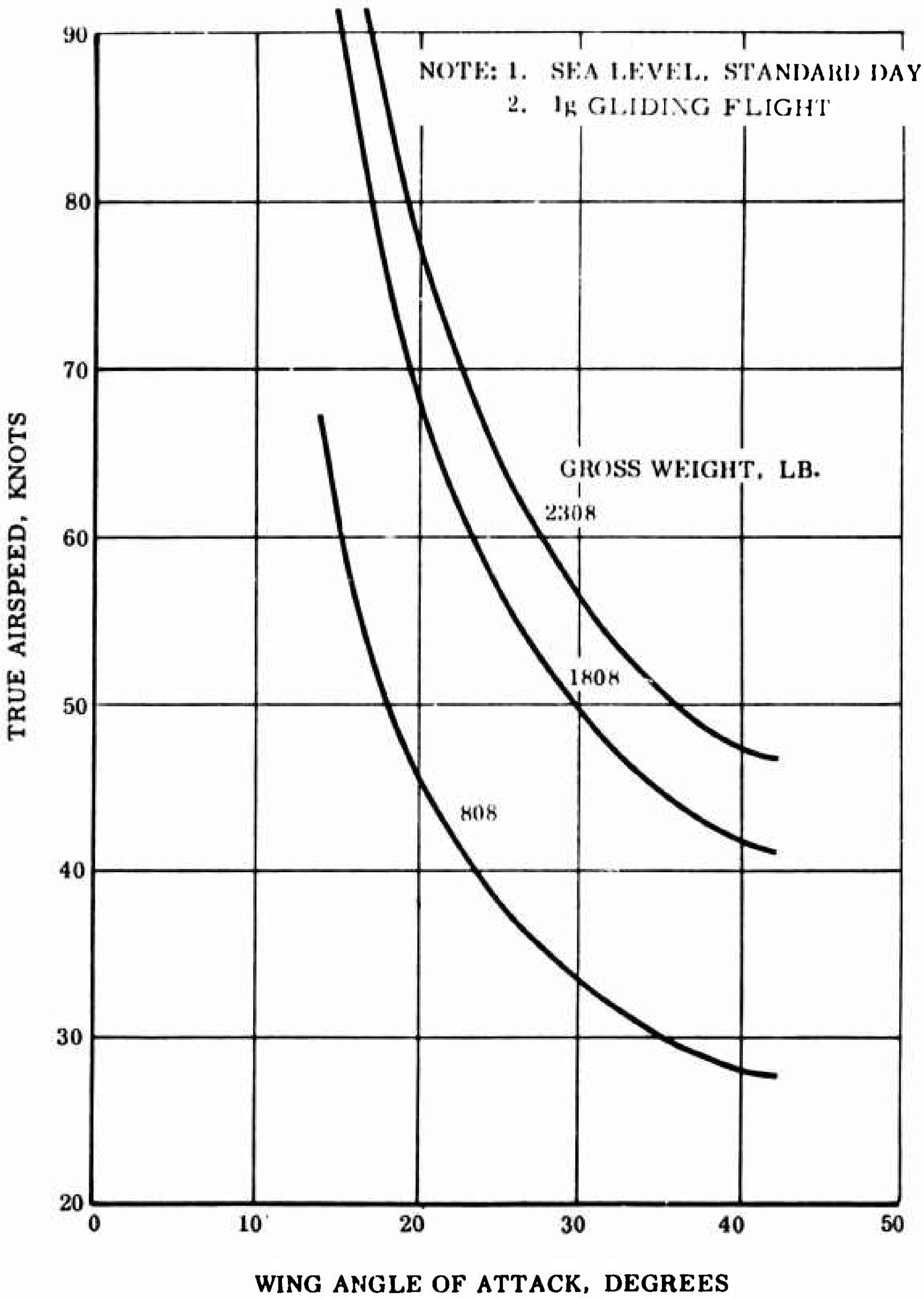


Figure 34. True Airspeed Versus Wing Angle of Attack for Trimmed Flight

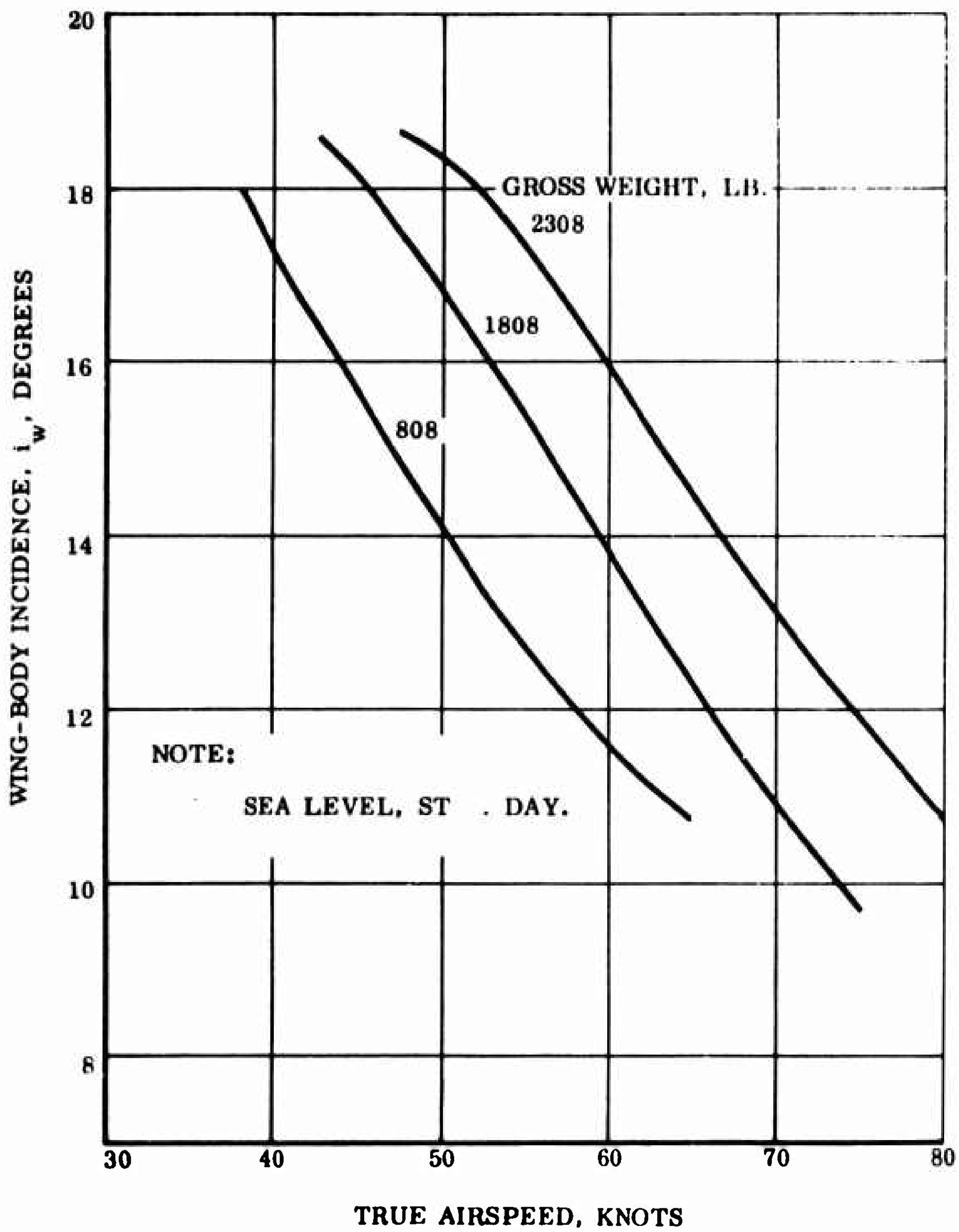


Figure 35. Wing-Body Incidence Angles

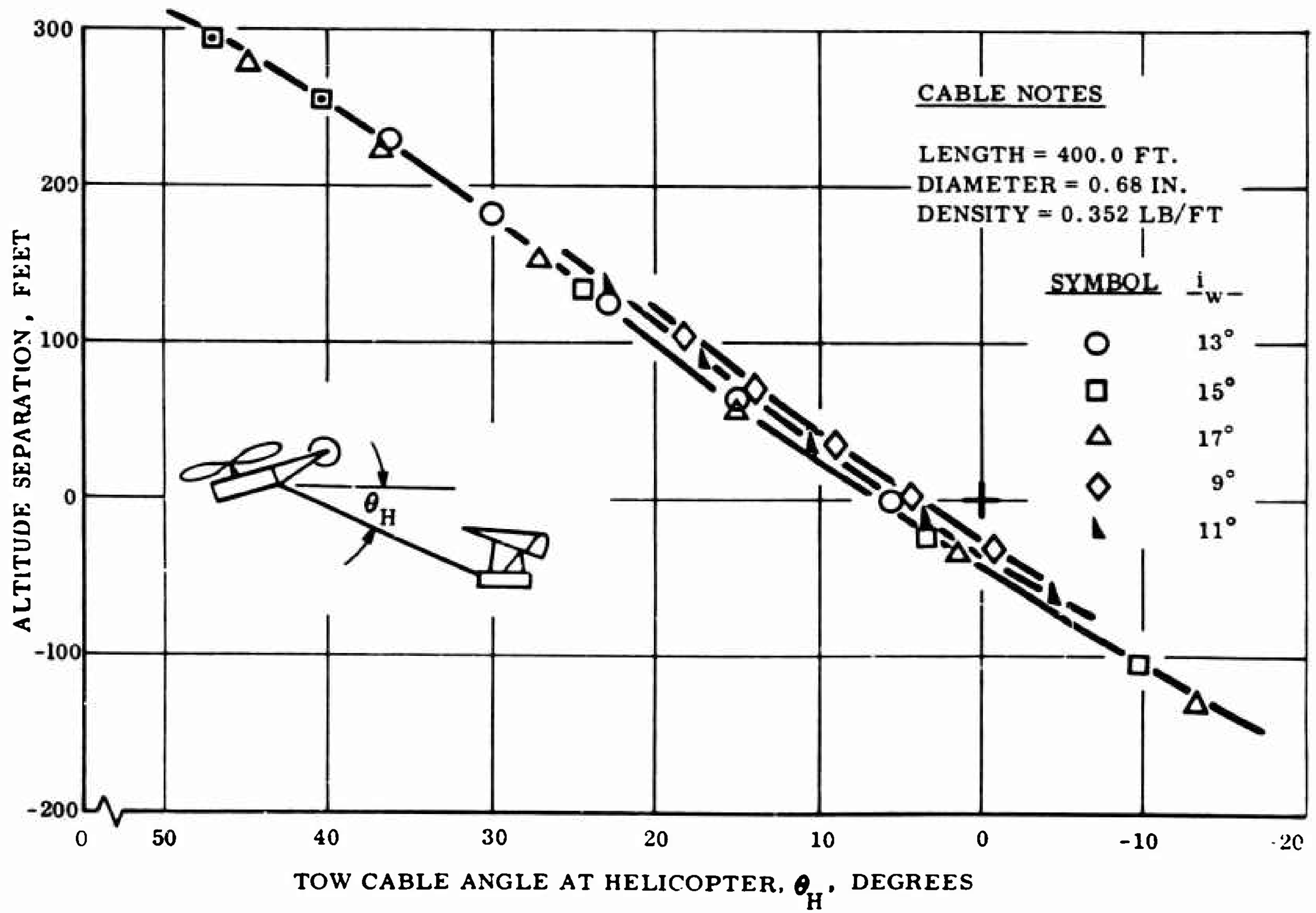


Figure 36. Vertical Separation Versus Tow Cable Angle

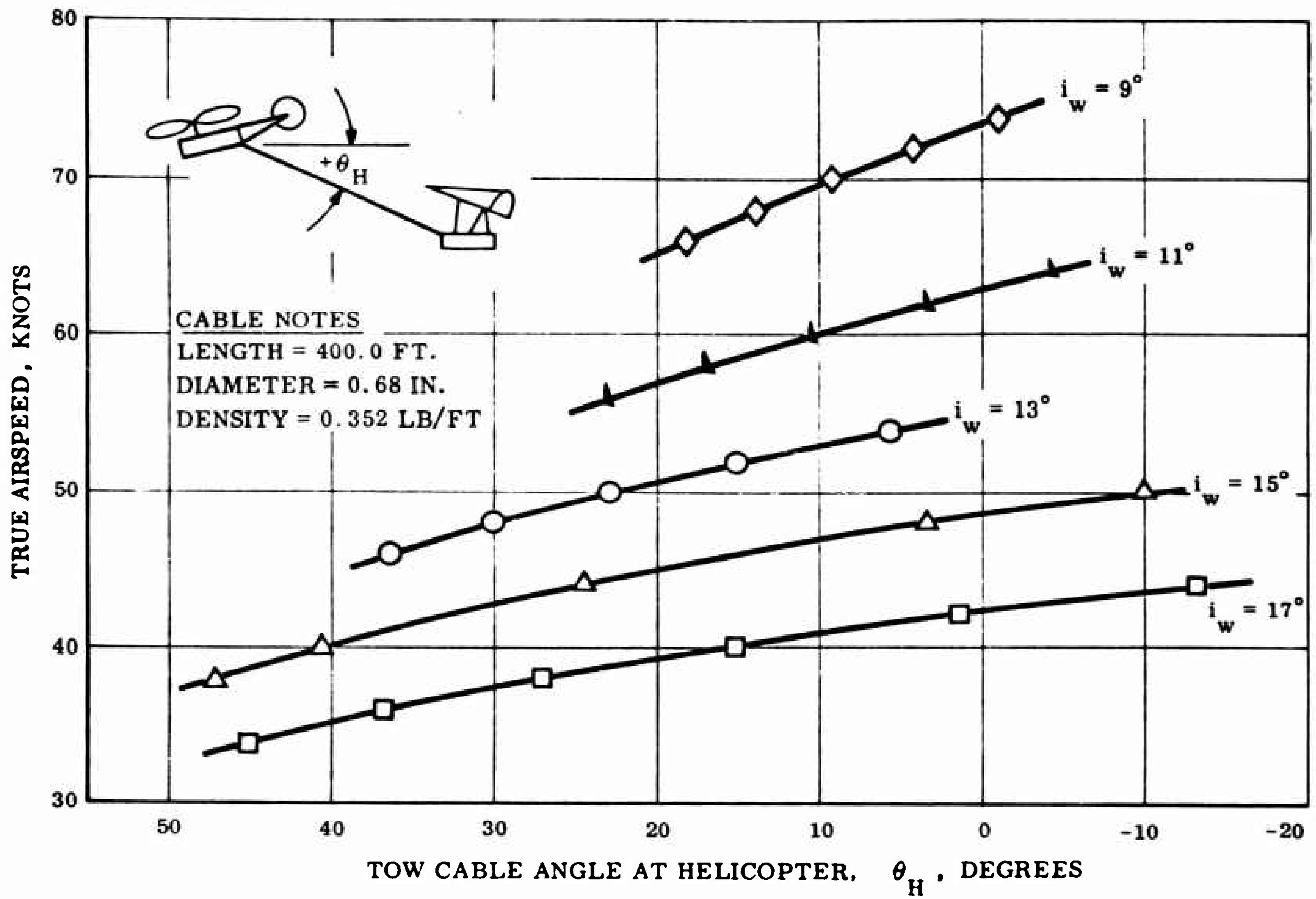


Figure 37. True Airspeed Versus Tow Cable Angle

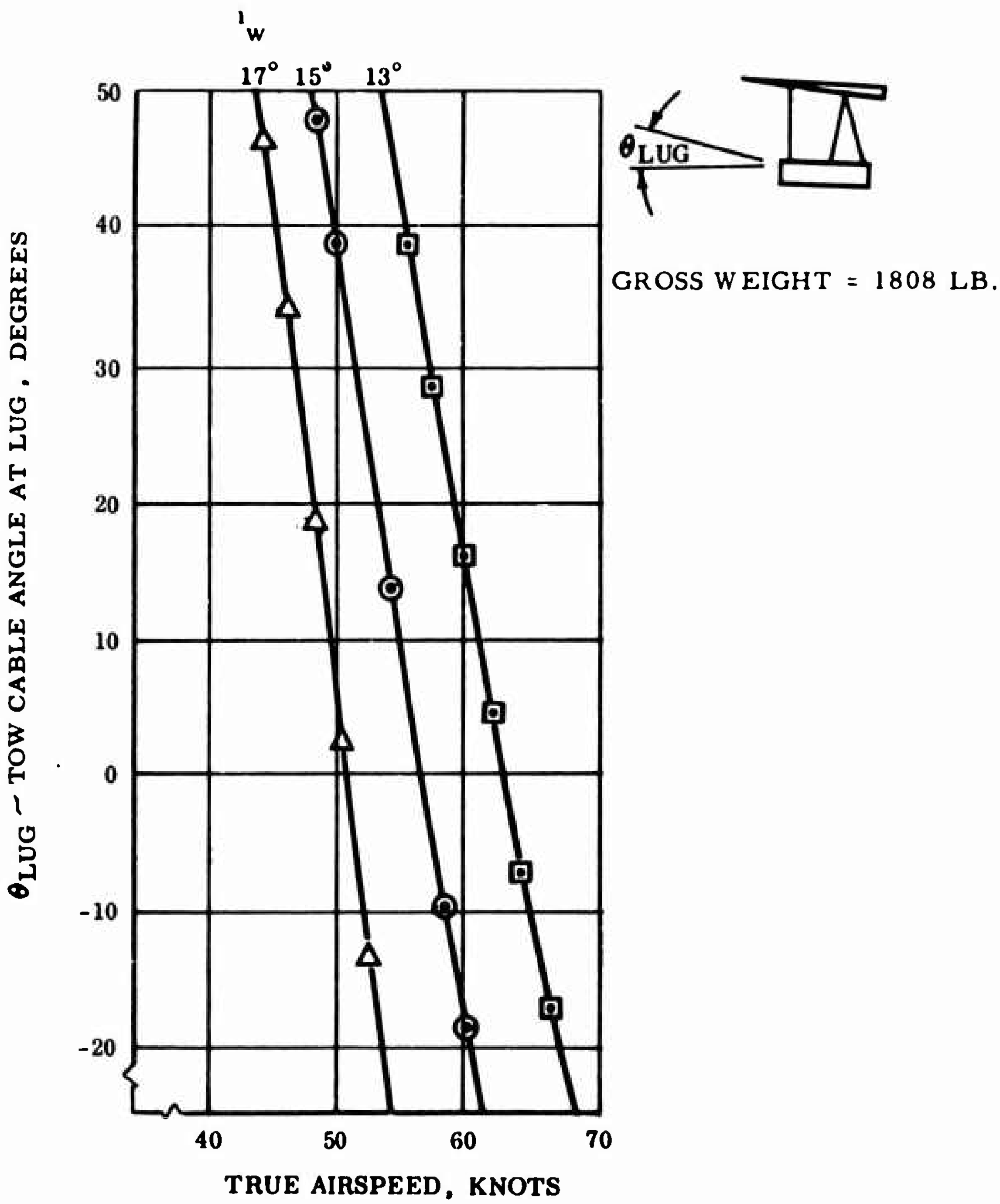


Figure 38. Tow Cable Angle at Glider

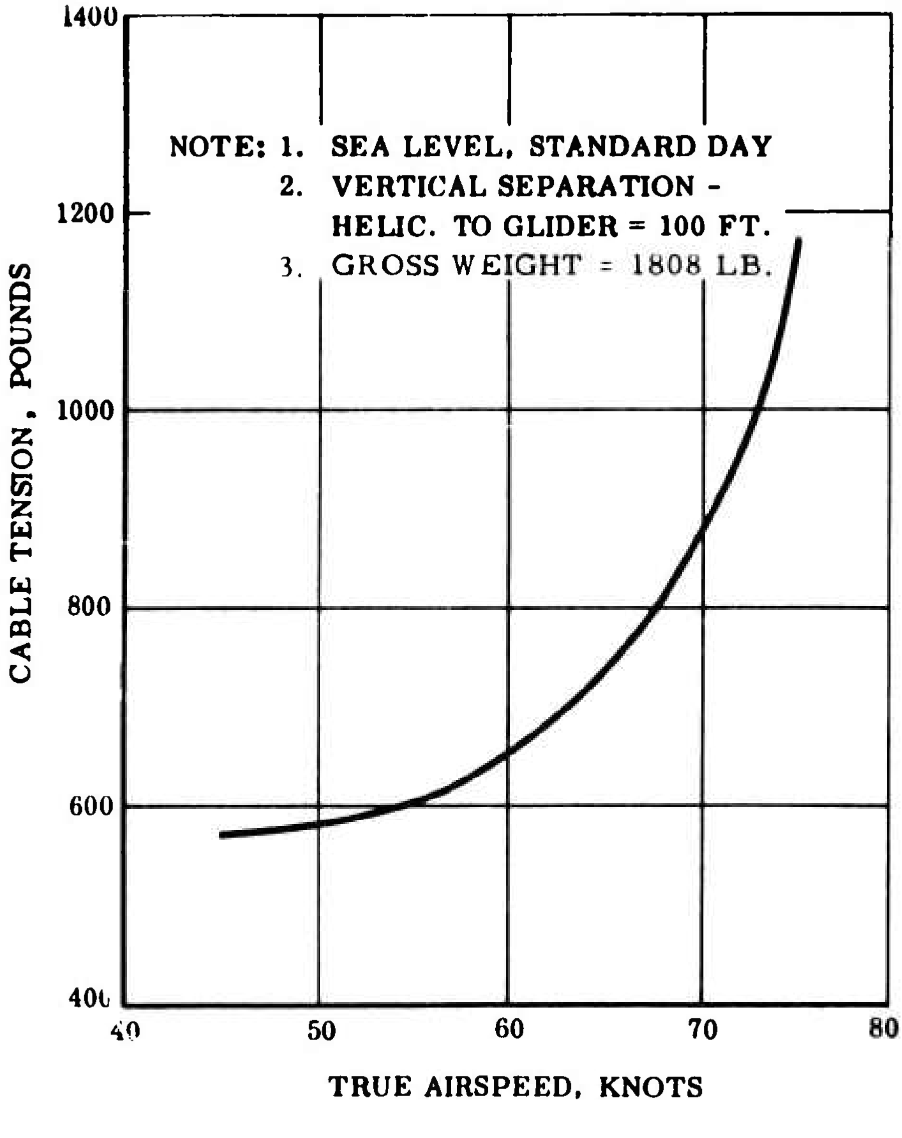


Figure 39. Tow Cable Angle

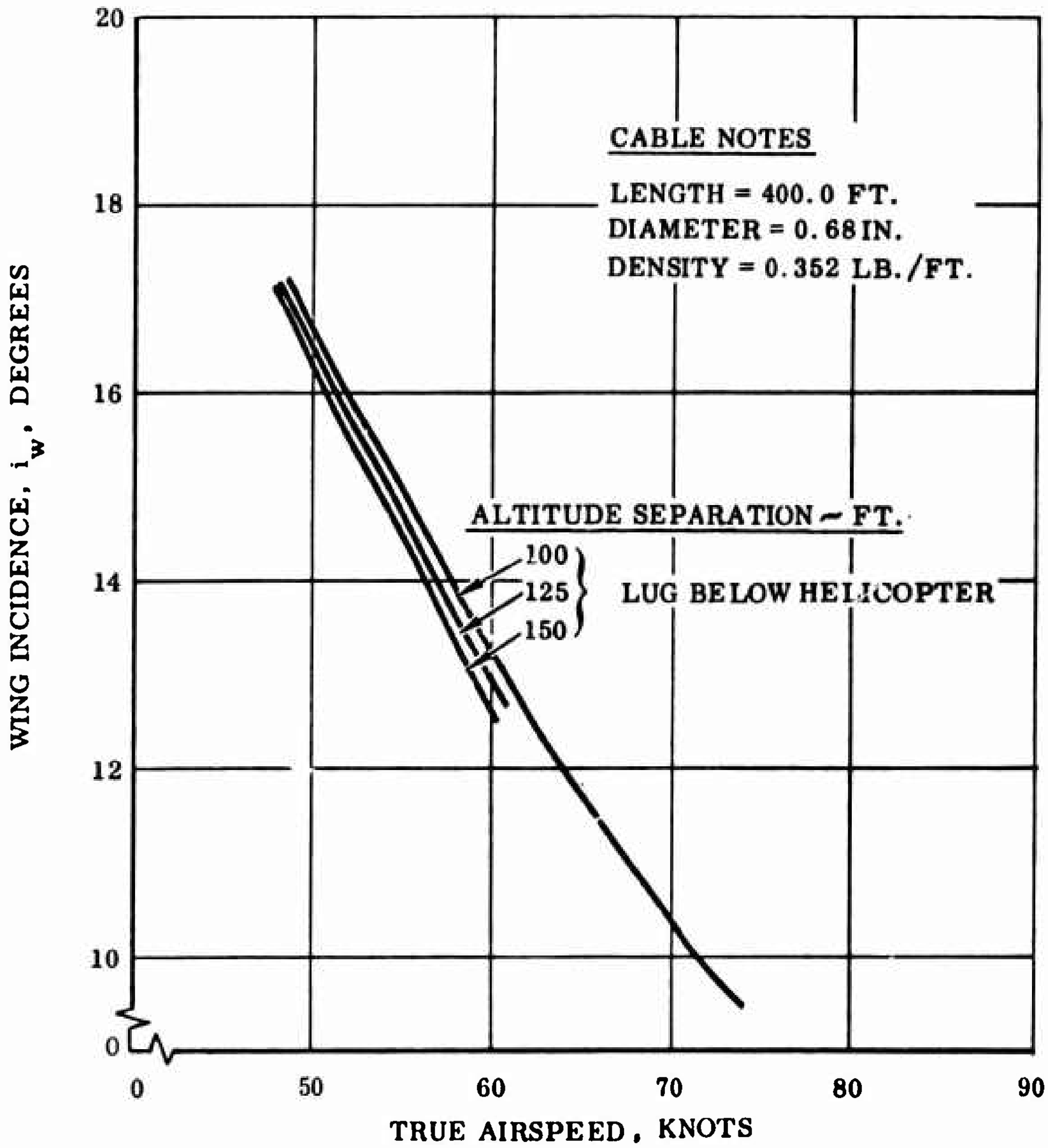


Figure 40. Wing Incidence Versus True Airspeed

LONGITUDINAL STATIC STABILITY

The off-tow longitudinal static margin, $C_{m_{C_L}}$, was calculated from the following relation:

$$C_{m_{C_L}} = \frac{C_{m_\alpha}}{C_{L_\alpha}}$$

Values of C_{m_α} were obtained by taking slopes of the C_m versus α curves discussed previously. C_{L_α} is .0405 per degree.

The variation of $C_{m_{C_L}}$ with lift coefficient is shown in Figure 41, indicating stable values throughout the usable C_L range.

LATERAL-DIRECTIONAL STATIC STABILITY

The lateral-directional stability parameters, C_{Y_β}, C_{m_β}, C_{ℓ_β}, for the wing alone are presented in Figure 42. Data bases were Ryan and NASA wind tunnel tests. Body, strut, and tail contributions were calculated using standard estimating techniques.

C_{Y_β}, C_{m_β}, and C_{ℓ_β} for the complete glider off tow were obtained by transferring the wing terms to the aircraft center of gravity and by adding the body, strut, and tail contributions as follows:

$$C_{Y_{\beta_{cg}}} = C_{Y_{\beta_W}} + C_{Y_{\beta_B}} + C_{Y_{\beta_S}} + C_{Y_{\beta_t}}$$

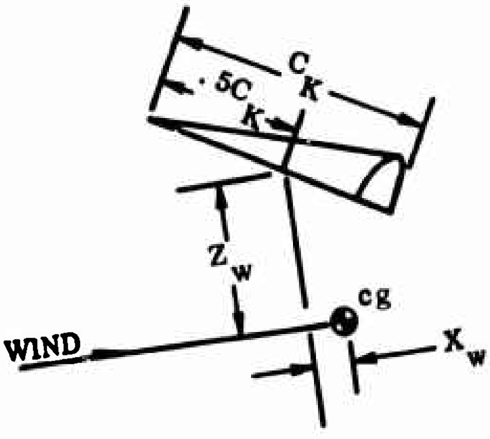
$$C_{M_{\beta_{cg}}} = C_{M_{\beta_W}} + C_{M_{\beta_B}} + C_{M_{\beta_S}} + C_{M_{\beta_t}} \quad \text{where,}$$

$$C_{M_{\beta_W}} = C'_{M_{\beta_W}} + C_{Y_{\beta_W}} (X_W/b)$$

$$C_{\ell_{\beta_{cg}}} = C_{\ell_{\beta_W}} + C_{\ell_{\beta_B}} + C_{\ell_{\beta_S}} + C_{\ell_{\beta_t}} \quad \text{where,}$$

$$C_{\ell_{\beta_W}} = C'_{\ell_{\beta_W}} + C_{\gamma_{\beta_W}} (Z_w/b)$$

Subscripts W, B, S, and t denote wing, body, struts, and tail respectively. The prime superscript refers the derivative to the wing midkeel point. All terms are in the stability axis system. X_w and Z_w are defined in the following sketch:



X_w is positive for mid-keel point forward of center of gravity.

Z_w is negative for wing above center of gravity.

The estimated lateral-directional static stability for the complete glider off tow is presented in Figure 43, which shows stable values of C_{ℓ_β} and C_{n_β} throughout the speed range.

DYNAMIC STABILITY

A detailed analysis of the on-tow dynamic stability of towed gliders is presented in the Final Report for the U.S. Army Air Cargo Delivery System (Reference 4). Subsequent flight test experience has shown that if a flexible wing aircraft is stable in gliding flight, it will be stable under tow. For this reason, only the off-tow dynamic stability of the LUG system has been analyzed, and the results of these investigations are presented in the following paragraphs.

LONGITUDINAL DYNAMIC STABILITY

Longitudinal dynamic stability of the glider in free flight was calculated by an IBM 704, using stick-fixed small perturbation equations.

The equations used by the program are based on equations developed in BUAER Report AE-61-4, "Dynamics of the Airframe" (Reference 1).

The equations are:

$$\dot{U} = X_U U + X_{\dot{w}} \dot{W} + X_w W + X_q \dot{\Theta} + X_{\delta_e} \delta_e - g (\cos \gamma_o) \theta$$

$$\dot{W} = Z_U U + Z_{\dot{w}} \dot{W} + Z_w W + (U_o + Z_q)\dot{\Theta} + Z_{\delta_e} \delta_e - g (\sin \gamma_o) \theta$$

$$\ddot{\Theta} = M_U U + M_{\dot{w}} \dot{W} + M_w W + M_q \dot{\Theta} + M_{\delta_e} \delta_e$$

The symbol definitions were considered too lengthy to be repeated herein; however, these definitions may be found in the referenced report if desired.

Time and cycles to damp to 1/2 amplitude in free flight are presented in Figure 44 for the phugoid and short-period modes indicating stable longitudinal dynamics throughout the speed range.

LATERAL-DIRECTIONAL DYNAMIC STABILITY

The methods used to estimate lateral-directional dynamic stability off tow are similar to those utilized for the longitudinal dynamics; i.e., small perturbation equations solved by IBM 704.

The stick-fixed lateral-directional perturbation equations, based on equations developed in BUAER Report AE-61-4, are:

$$\dot{\beta} = Y_{\beta}\beta + Y_{p}\dot{\Theta} + Y_{r}\psi + Y_{\delta_a}\delta_a + Y_{\delta_r}\delta_r - \dot{\psi} + \frac{g}{U_o}(\sin\gamma_o)\psi$$

$$\ddot{\phi} = L_{\beta}\beta + L_{p}\dot{\phi} + L_{r}\dot{\psi} + L_{\delta_a}\delta_a + L_{\delta_r}\delta_r + \left(\frac{I_{XZ}}{I_X}\right)\ddot{\psi}$$

$$\ddot{\psi} = N_{\beta}\beta + N_{p}\dot{\phi} + N_{r}\dot{\phi} + N_{\delta_a}\delta_a + N_{\delta_r}\delta_r + \left(\frac{I_{XZ}}{I_Z}\right)\ddot{\phi}$$

All symbols are defined in the referenced report.

The following data were obtained from the lateral-directional small perturbation program. These data are plotted in Figures 45 and 46.

Figure	Mode	Characteristics
45	Dutch roll	1/time to 1/2 amplitude
45	Dutch roll	1/cycles to 1/2 amplitude
45	Spiral	1/time to 1/2 amplitude
46	Roll	1/time to 1/2 amplitude

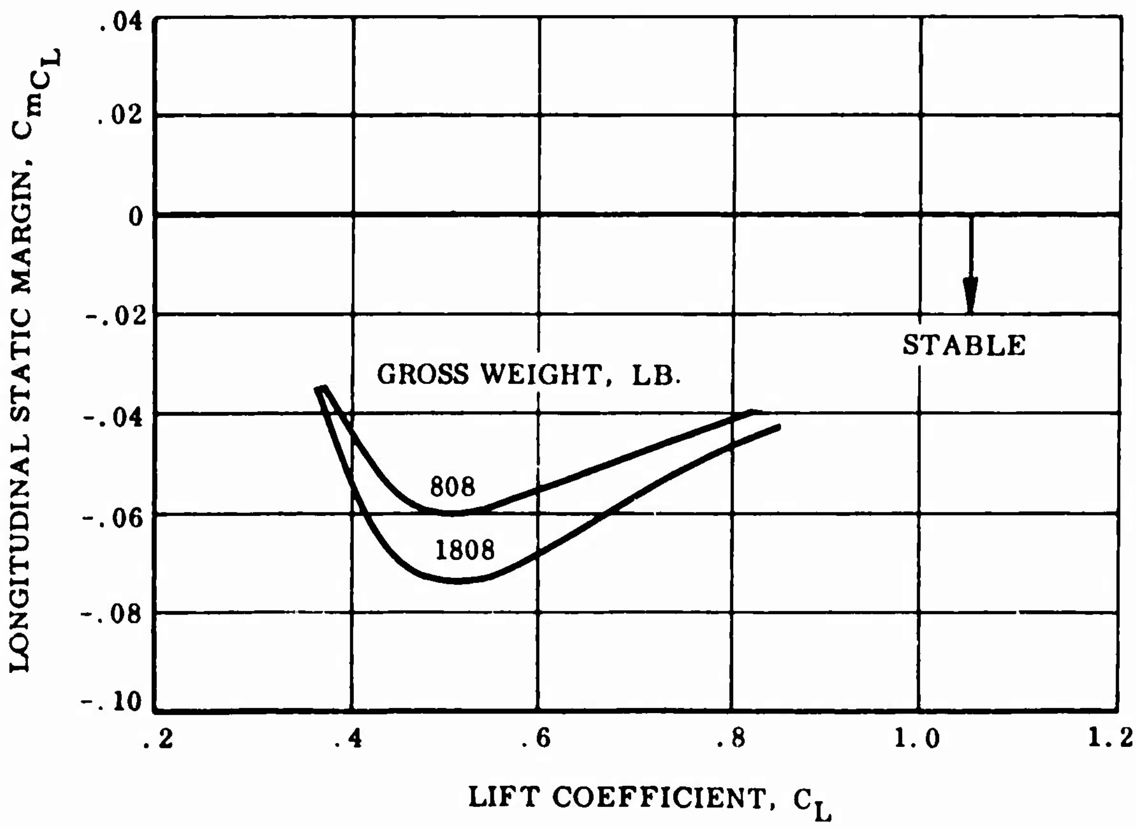


Figure 41. Longitudinal Static Margin

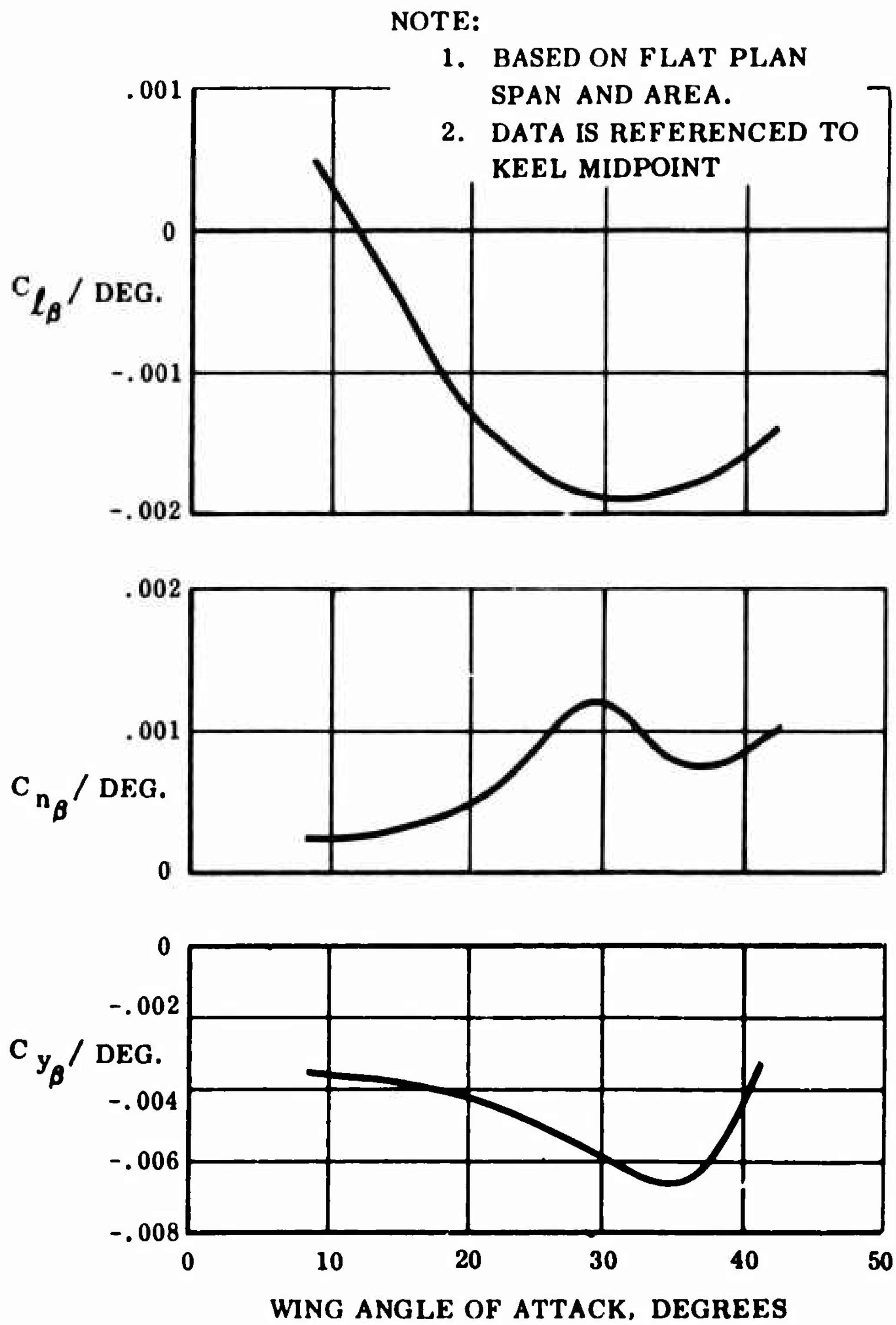


Figure 42. Lateral-Directional Static Stability, Wing Only

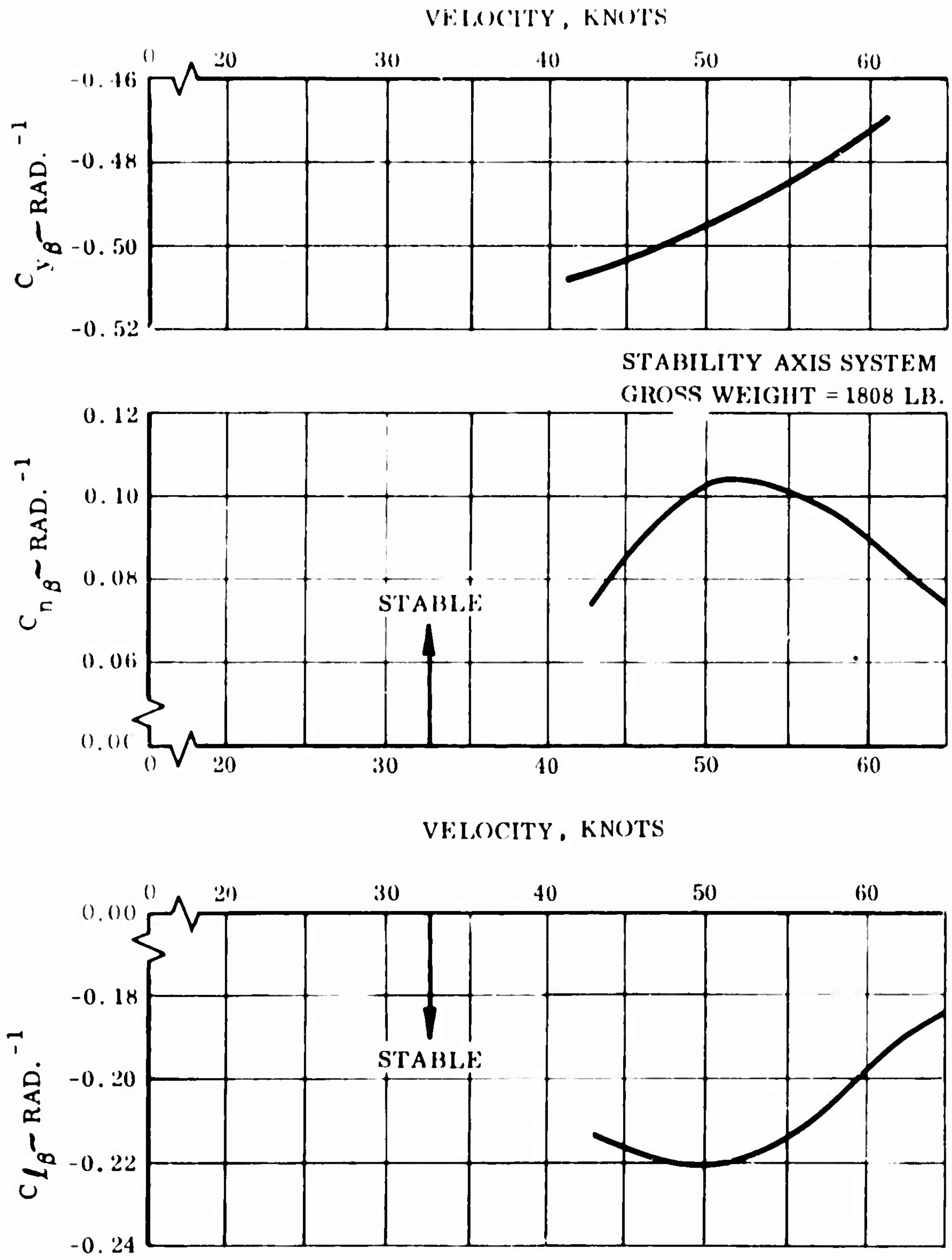


Figure 43. Lateral-Directional Static Stability, Complete Aircraft

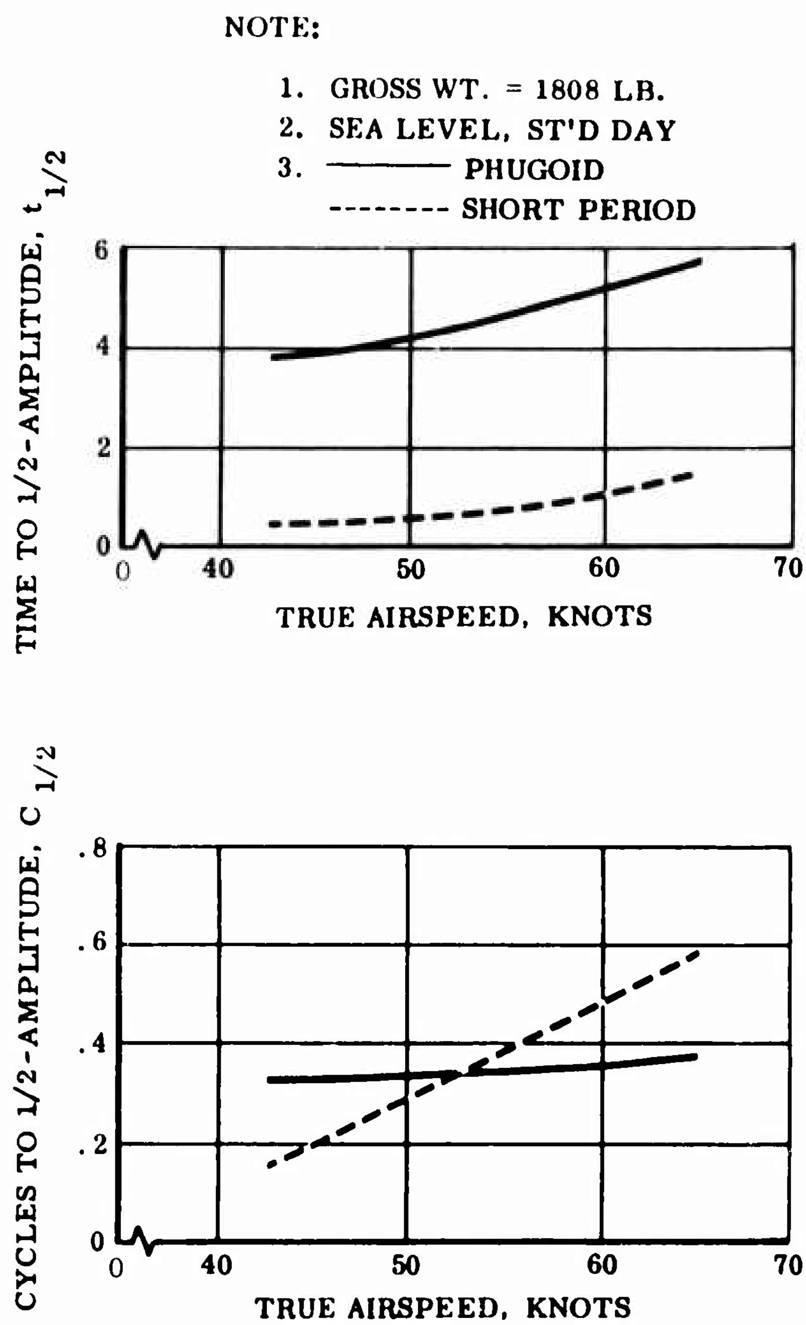


Figure 44. Longitudinal Dynamic Stability

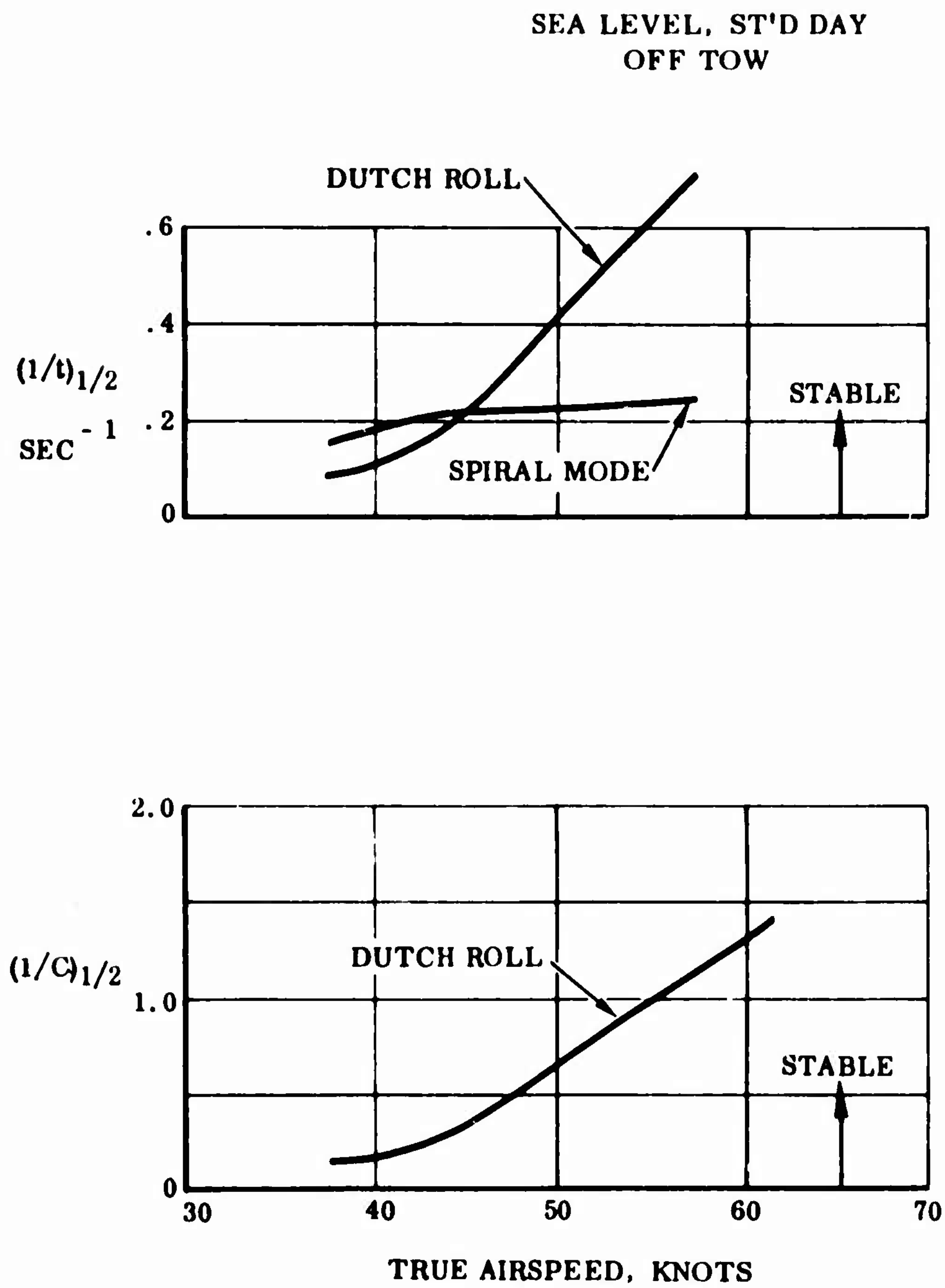


Figure 45. Lateral-Directional Dynamic Stability

SEA LEVEL, ST'D DAY
OFF TOW

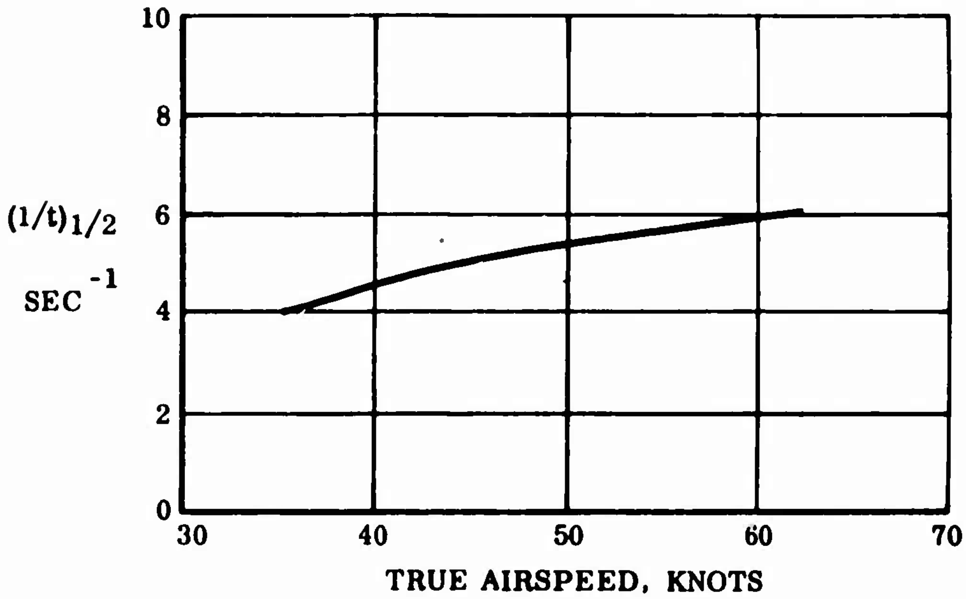


Figure 46. Lateral Dynamic Stability

STRUCTURAL ANALYSIS

The operational Flexible Wing Light Utility Glider has been designed with a philosophy of simplicity and low cost as the most important criteria. This basic design philosophy has necessitated lesser structural efficiency with an accompanying weight penalty imposed on the vehicle. Many design details have been influenced by the results of the Air Cargo Glider System designed, fabricated and flight tested by Ryan under contracts DA 44-177-AMC-868 (T) and DA 44-177-AMC-122 (T).

DESIGN CRITERIA

The structural design criteria for the vehicle is based on the conditions to be incurred in operation. The criteria is substantially the same as that which was established for previous Flex Wing Air Cargo Gliders. Any fundamental deviation from the original criteria is made based on results obtained from flight tests of the Air Cargo Glider.

Flight Loading Conditions

The vehicle is capable of sustaining the loads incurred from flight maneuvers under free flight and towed flight conditions. The loads resulting from these conditions are considered to be limit loads and are increased by a factor of safety of 1.25 to obtain ultimate design loads. The design gross weight is 2200 pounds.

The following design airspeeds have been established:

Maximum level speed, V_H = 70 knots

Limit Speed, V_L = 105 knots

Maximum Design Gust Speed, V_G = 65.6 knots

Symmetrical Maneuvering Envelope

The symmetrical flight maneuvering and vertical gust load factor envelope is shown in Figure 47. The envelope is defined by the limit maneuvering loads factor of 2.50 and the design gust conditions.

Design Speeds:

V_H = 70 knots, maximum level speed

$V_L = 1.5\ V_H$ = 105 knots, dive speed

V_S = 45.75 knots, stall speed

Design weight = 2200 pounds

$$\text{Wing loading } W/S = \frac{2200}{250} = 8.8 \text{ lb./ft.}^2$$

Stall parameter:

$$\frac{k \rho_o V_e^2 C_{N_{max}}}{2\ (W/S)} \quad \text{Ref: MIL-A-8861}$$

$k = 1.25$

$\rho_o = 0.002378$ slug/ft.^{2}

$C_{N_{max.}} = 1.24$ per radian

$$= \frac{(1.25)\ (.002378)\ (1.24)\ V_e^2}{(2)\ (8.8)} = 0.0002093\ V_e^2 \quad (V_e \text{ in fps})$$

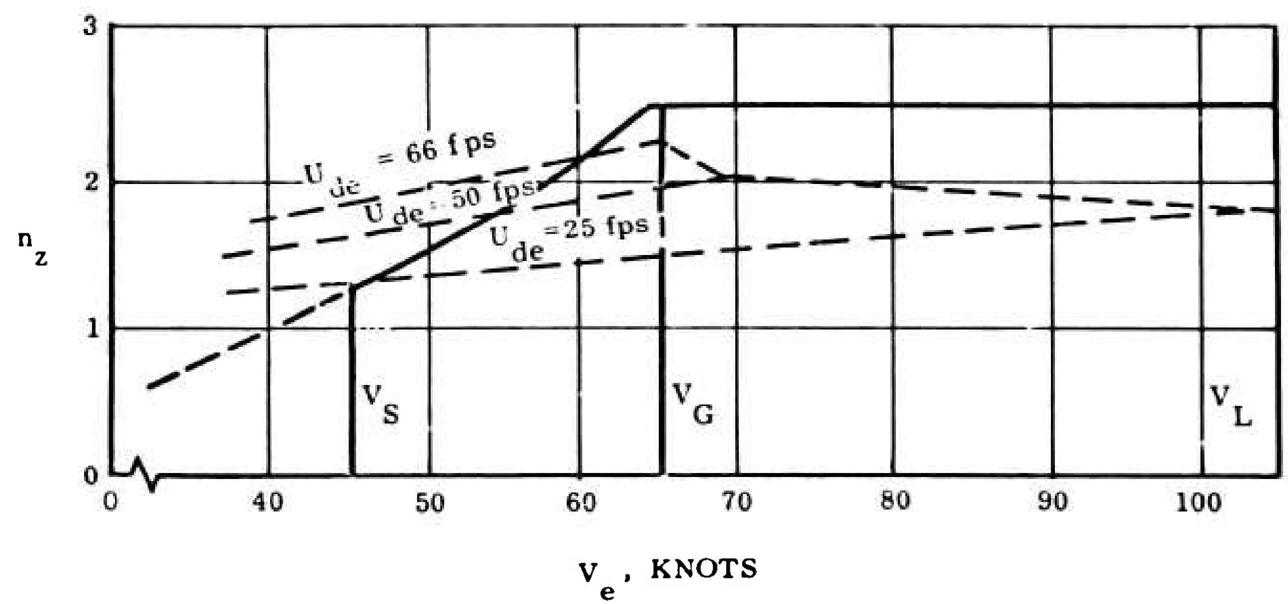


Figure 47. V - n Diagram; Symmetrical Maneuvering and Gust

Gust Parameters

The vertical gust conditions result in critical loading over most of the velocity range. The gust load factor was defined as follows:

$$n_g = 1 + \frac{\rho_o V_e U_{de} C_{N_A} K_W}{2 (W/S)} \qquad \text{Ref: MIL-A-8861}$$

where ρ_o = 0.002377 slugs/ft.^{2}

V_e = vehicle speed in ft/sec.

U_{de} = design gust velocity

= 66 ft./sec. for $V_e \leq V_G$

= 50 ft/sec. for $V_e = V_H$

= 25 ft/sec. for $V_e = V_L$

C_{N_A} = 2.208 per radian Ref: Figure 31

$$K_W = \frac{.88\ U}{5.3 + U} \qquad \text{Ref: MIL-A-8861}$$

$$U = \frac{2\ ({}^W/S)}{g\ c\ C_{m_\alpha}\ \rho_o}$$

$\frac{W}{S}$ = 8.8 lb/ft^2, wing loading

g = 32.2 ft/sec^2, acceleration of gravity

$c = 9.4$ ft., mean geometric chord

$$U = \frac{2\ (8.8)}{(32.2)\ (9.4)\ (2.208)\ (.002378)} = 11.07$$

$$K_W = \frac{(.88)\ (11.07)}{5.3 + 11.07} = 0.594$$

For $V_G = 50$ fps:

$$N_g = 1 + \frac{(.002378)\ (50)\ (118.16)\ (2.208)\ (.594)}{2\ (8.8)}$$

$$= 2.047 \text{ @ } V_e = 70 \text{ knots}$$

For $V_G = 66$ fps:

$$V_G = V_S \sqrt{N} = 45.75 \sqrt{2.047} = 65.6 \text{ kts.}$$

$$= 110.7 \text{ fps}$$

$$N_G = 1 + \frac{(.002378)\ (66)\ (110.7)\ (2.208)\ (.594)}{2\ (8.8)}$$

$$= 2.293$$

For $V_G = 25$ fps:

$$V_e = V_L = 105 \text{ Kts.}$$

$$= 177 \text{ fps}$$

$$N_G = 1 + \frac{(.002378)\ (25)\ (177.24)\ (2.208)\ (.594)}{2\ (8.8)}$$

$$= 1.787$$

Note: A linear relationship may be assumed between the terminal points of the vertical gust envelope limits.

Ref: CAM-3b

Lateral Gust Condition

The lateral gust load factor envelopes shown in Figure 48 were determined in a manner similar to the vertical gust envelope with the following exceptions:

$K_W = 1.0$ Ref: MIL-A-8861

C_{y_β} = See Figure 42

The side force derivative C_{y_β} is available from unpublished NASA wind tunnel data for the wing alone and is shown in Figure 42. The lateral gust factors have been determined for steady equilibrium flight, the angle of attack α_w being determined from Figure 34. The lateral gust factor is given by

$$N_y = 1 + \frac{\rho_o V_e U_{d_e} C_{y_\beta} K_w}{2 (W/_S)}$$ Ref: MIL-A-8861

Where ρ_o = sea level density of air, lb-sec^2/ft.^{4}

V_e = equivalent airspeed of the glider, fps

U_{d_e} = equivalent gust velocity, fps

C_{y_β} = side force derivative per degree

$K_w = 1.0$

$W/_S$ = wing loading, lb/ft.^{2}

Landing and Ground Handling Loads

The structure shall be designed for the landing and ground handling conditions outlined below. These are to include, but not necessarily be limited to, dynamic spin-up and spring-back loads.

1. Symmetrical Landing

2. Side Drift Landings

3. Towing and Jacking

The design landing gross weight shall be 2200 pounds. The landing gear including wheels, springs, struts, and supporting structure shall be designed for a limit landing load factor of 2 g at the gear. Wing lift may be considered equal to two-thirds of the gross weight.

The landing skids, body structure, wing structure, and wing support structure shall be designed to the following ultimate load factors acting separately. The loads calculated are to be reacted by inertia.

Vertical .... 10.0 down

Lateral .... 4.0 side

Longitudinal .... 6.0 forward

Cargo Installation

The following loads are applicable for the design of cargo tie-down fittings and their carry-through structure. The loads may be considered as ultimate and as acting separately. The load factors are as follows:

Vertical .... 10.0 down

Lateral .... 4.0 side

Longitudinal .... 6.0 forward

Cargo flooring shall be capable of withstanding an ultimate design pressure of 3.5 psi acting locally.

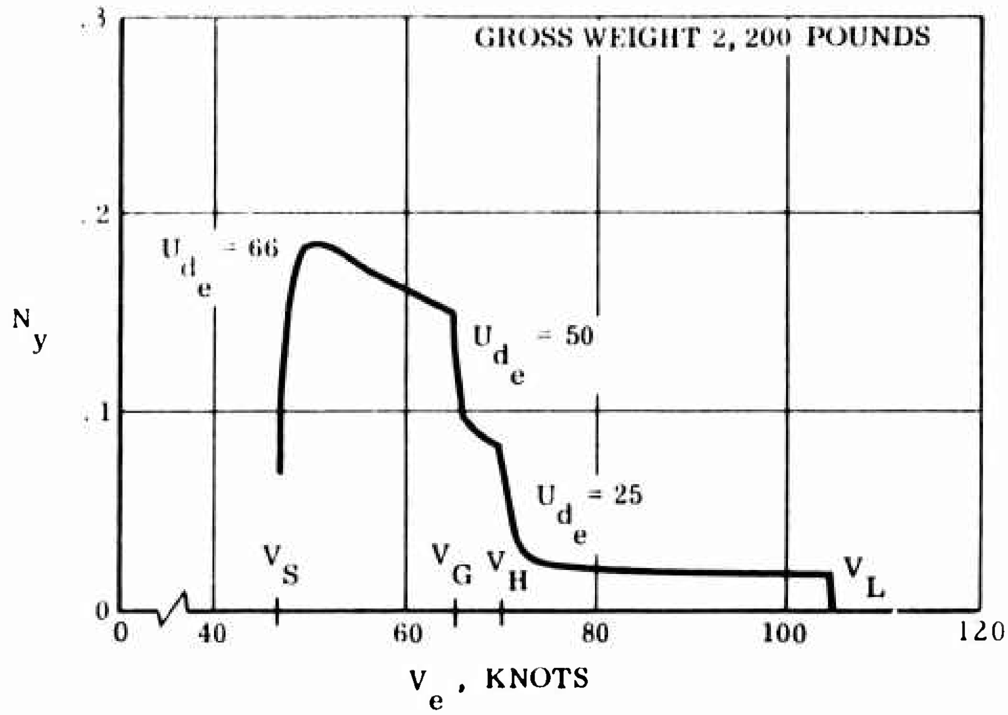


Figure 48. V n Diagram; Lateral Gust

STRESS ANALYSIS

The methods of stress analysis used in the design of the LUG are similar to those utilized in Reference 4.

Standard methods of analysis were employed throughout. It is significant to note that a number of negative margins of safety exist in the analysis of the wing structure. The detailed loads analysis conducted in the formulation of this technical report revealed some basic errors in the preliminary analysis which had been conducted during the design phase of the program. At the period of writing of this report, the LUG had undergone extensive flight testing, and it is noteworthy that the wing structure did not experience any structural failures. It is the contractor's opinion that the discrepancy can be attributed to two possible reasons. First, the basic wind-tunnel data used in the analysis is not of sufficient accuracy to calculate true wing loads. Secondly, the arbitrary design load factor of 2.5 g may not be realistic for flexible wing systems of the rigid construction and perhaps should be somewhat lower.

In addition, flight test experience indicates that the nature of the effect of landing loads on the wing support structure may not be fully understood. While the assumptions used for these loads resulted in acceptable stress levels, compressive failures of the struts occurred during flight test.

FLIGHT TEST PROGRAM

TEST PROCEDURES

The test program was conducted in a logical sequence from ground test phase through flight test operations. Ground tests began with truck tows of the control platform only, followed by truck tows of the assembled wing and platform. Flight operating procedures were established which included both ground checkout and airborne operation.

An airborne controller located in the tow vehicle monitored LUG tow characteristics throughout the flight until release. A ground controller located at a "radio jeep" monitored the free flight and towed-on landings. Level flight runs at various airspeeds and wing incidence settings were made to check LUG towed flight characteristics and to determine speed envelope boundaries. Control characteristics in both manual and automatic flight regimes were checked. Flare system evaluations were made on each landing to determine the best configuration for touchdown.

TEST RESULTS

A total of 33 flight test operations were conducted between 23 July 1964 and 17 September 1964. All testing was accomplished at the Yuma Test Station, Yuma, Arizona.

Four LUG vehicles were constructed for use on this flight test program. One extra platform assembly was built to replace one damaged in a landing incident.

Tow Characteristics

LUG towing characteristics on the ground are good and present no limitations on helicopter operation. The LUG can be lined up 90 degrees from the direction of tow and will straighten out for a smooth stable takeoff.

Brakes on the rear wheels remain on during takeoff and landing which proved to be an effective braking system. On takeoff, the wing fills at about 15 KIAS.

Lift-off is typical with front wheels leaving the ground first, followed by complete vehicle lift-off. With either the H-34 or a UH-1 helicopter, the LUG climbout was approximately 500 feet per minute with a 15-degree flight path angle. Airspeed for this climb is 50 to 60 KIAS. Cruise speed is a function of wing-incidence angle. By varying the wing incidence from 10 to 18 degrees, the tow speed can be varied from 30 to 70 KIAS. These airspeed limits are defined by altitude separation and/or depression angle between the helicopter and the glider. Upper limits are approximately 100 feet, or 15 degrees. Lower limits were approximately 350 feet and 60-70 degrees. Tow bridle configuration and alignment with respect to the glider center of gravity can appreciably change the flight characteristics and the towing speed envelope of the glider. The initial configuration tested resulted in pitch and roll instability and a narrow speed range. By moving the bridle alignment assembly up 10 inches on the forward A-frame, the glider stability was improved and the speed envelope increased by 20 knots. Figure 49 shows the airspeed envelopes for the various configurations tested.

For tow-on landings, a straight-in approach with a 250-foot-per-minute rate of descent and an airspeed between 45 and 50 KIAS were used. Abrupt changes in airspeed on final approach must be avoided to prevent a pendulum or swinging effect of the glider. For best landing results, the control platform pitch attitude should be about 2 to 3 degrees nose up. A ground controller was used to call out terrain altitude to the helicopter pilot during all landing approaches. Successful landings were made with wing-incidence settings from 12 to 16 degrees and associated speeds from 30 to 50 KIAS. See Figure 50.

Free Flight Characteristics

Eight free flights were made during this test program. Additional free flights will be required to evaluate fully the gliding and control characteristics of the glider; however, the feasibility of free flight has been established.

The wing-incidence setting and the tow airspeed at time of release appear to be critical. By changing the airspeed by 5 knots or the incidence angle by 1 degree, severe changes in glider pitch attitude were experienced immediately after release. The best release conditions experienced were 15 degrees wing incidence and 40 KIAS.

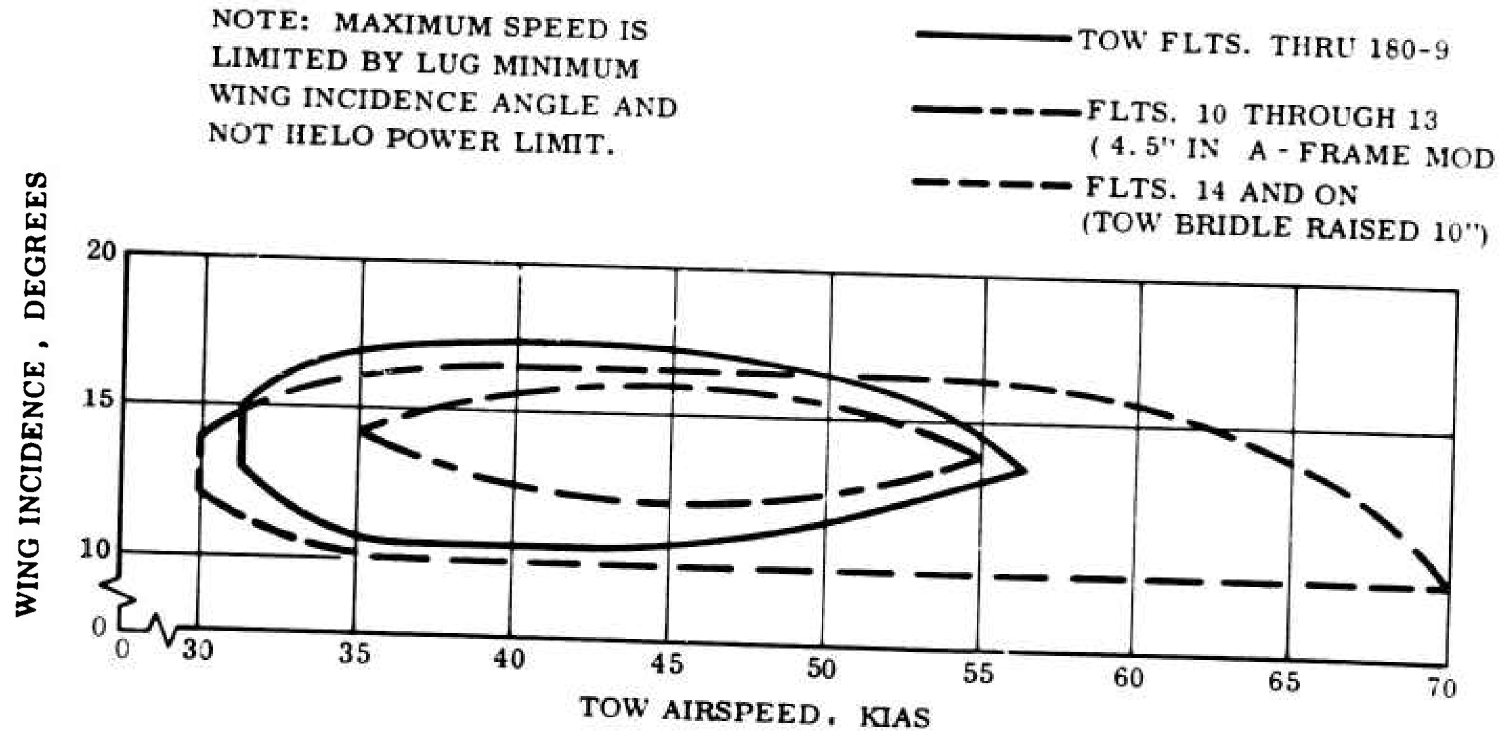


Figure 49. Tow Speed Envelope, Level Flight

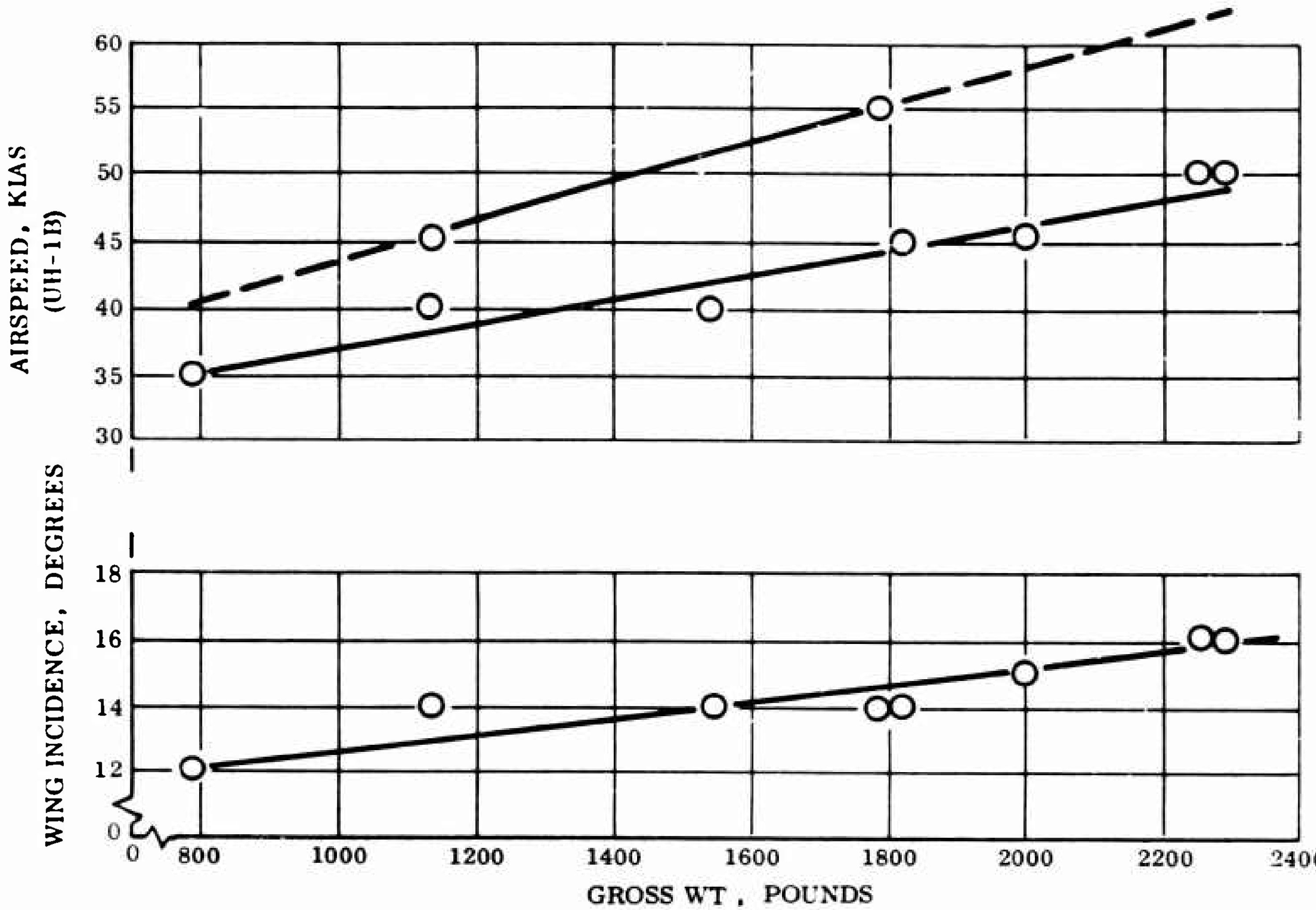


Figure 50. Landing Parameters

Initial wing roll rates of 10 degrees/second were much too high for effective remote control. With high roll rates, it becomes impossible to trim the glider for straight flight. By reducing the roll rate to 2 degrees/second, satisfactory control was obtained and straight trimmed flight was possible.

Only two attempts were made to evaluate homing control during free flight. On the first attempt, the maximum roll limits were ±4.5 degrees. During homing flight, the glider senses only maximum roll control deflections. The 4.5-degree roll angle proved to be sufficient to put the glider into a steep diving spiral from which recovery was not possible. On the second attempt, the roll limits were reduced to ±1 degree. The amount of deflection appeared to be insufficient for effective control. Further testing is required to evaluate homing control fully.

The flare system was evaluated on each free flight. An effective flare maneuver is dependent on the wing-incidence angle used for flare and the length of the flare pendant. The best free flight landing results were achieved with a 20-degree wing-incidence setting and a 20-foot pendant. Further testing is required to determine what effect glider weight would have on these parameters.

UH-1B TOWING CERTIFICATION

Concurrent with the LUG test program, a flight safety program relative to towing was accomplished on the UH-1B helicopter. Bell Aircraft Company personnel, including a test pilot, participated in the program. Tail rotor instrumentation and a stick plot board were utilized to obtain flight data. The Bell pilot flew all the UH-1B initial tow missions throughout the LUG weight range and free flight launches.

No excessive loads or loss of stick travel problems were encountered. At the conclusion of the program, a flight safety board issued a safety of flight certificate for the UH-1B helicopter towing the Light Utility Glider with the following restrictions:

a. The tow helicopter shall not exceed 6250 pounds gross weight.

b. The towed load will not exceed 2300 pounds plus the weight of the standard cable.

c. Flight crews during tow operations will consist of pilot, copilot, and trained observer.

d. Tow cable limitations will be 15 degrees above and 60 degrees below the horizontal. When these limits are exceeded, the towed load will be released. In no case will these limitations be exceeded.

e. Flight speed will conform with those in Figure 51.

FLIGHT TEST SUMMARY REPORTS

A summary of each flight test operation is presented in the following paragraphs. Ground taxi tests and cable-only tow tests (Operations 180-1 through 180-3) are not included.

Flight Operation 180-4 - This was the first flight of the LUG No. 1. Takeoff was made from the runway and the LUG was towed to the drop zone. Good dynamic characteristics were demonstrated under tow, and flight cruise speed range was 30-55 knots. A good landing was made on the drop zone. The body attitude was nose up on initial touchdown. No damage was sustained by the vehicle. The tow helicopter was the CH-34C; the glider gross weight was 1,145 pounds.

Flight Operation 180-5 - This flight used the same configuration as for flight 180-4. LUG No. 1 was again utilized. The test objective was to expand the flight envelope established previously. Takeoff was good. Wing incidence was varied during the flight to determine a velocity-wing-incidence envelope. The speed envelope was increased to 60 knots. The vehicle made a good landing and roll-out. The tow helicopter was the CH-34C.

Flight Operation 180-6 - The system center of gravity was moved aft 8 inches. Takeoff was at a wing-incidence angle of 18 degrees. This resulted in a nose high attitude at lift-off and wide lateral excursions. The flight was immediately aborted and the glider was landed from the abort maneuver. One wing support strut was slightly damaged on landing. Feasibility of abort maneuver was verified. A too-high wing incidence was cause for instability.

Flight Operation 180-7 - Test objective was to determine the flight envelope of the glider with a higher gross weight. Takeoff was from the active runway and the landing on the drop zone. The gross weight was 1,495 pounds. The

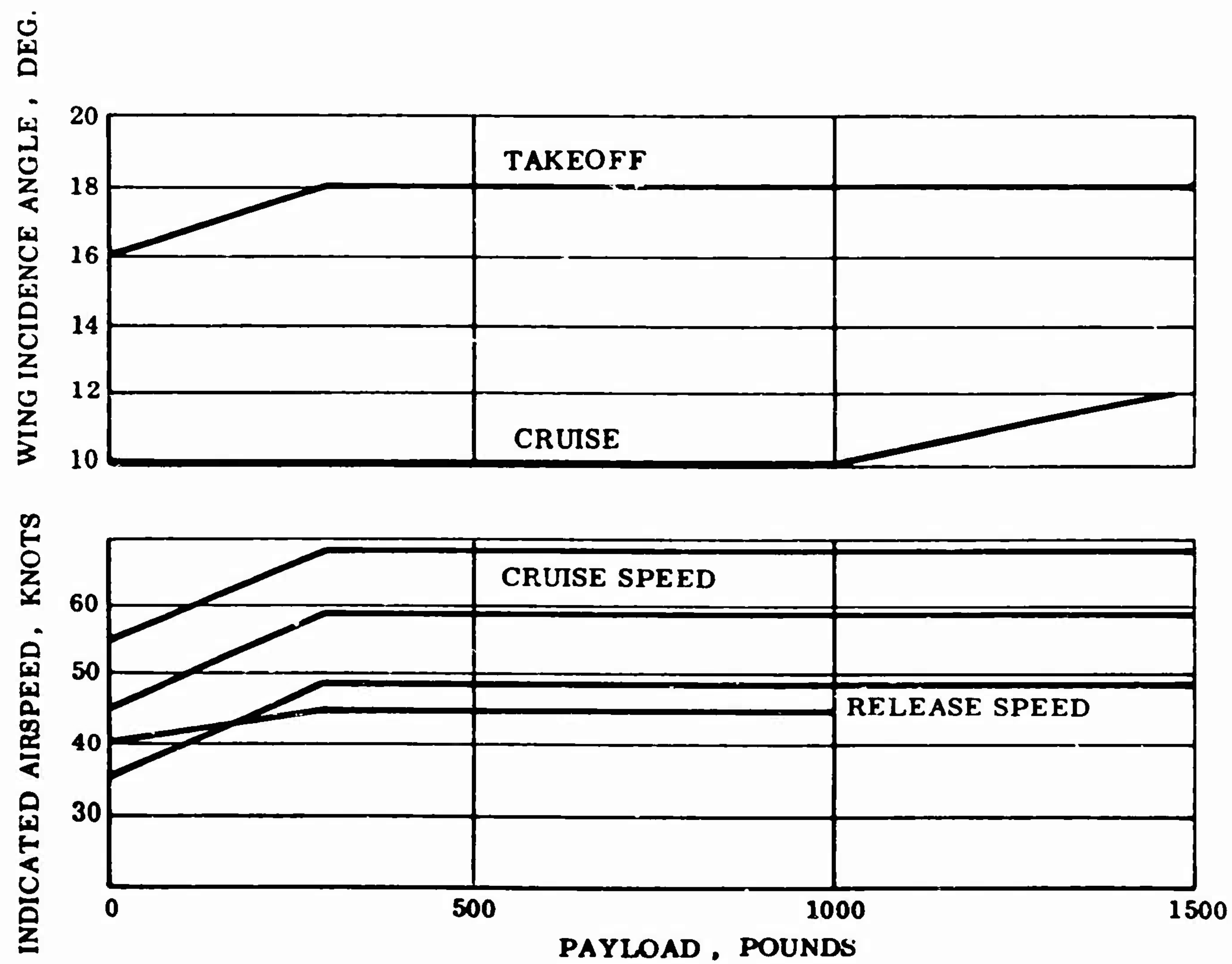


Figure 51. LUG Operating Conditions

speed envelope was determined as 35 knots to 50 knots. Flight characteristics were satisfactory. The landing roll-out was 250 feet. The flight duration was 55 minutes.

Flight Operation 180-8 - Test objective was to establish a flight envelope for the glider with zero payload. The gross weight was 775 pounds. The takeoff was from the runway and the landing was on the drop zone. The flight characteristics were satisfactory. The speed envelope was 35 to 50 knots at wing incidence settings of 10 degrees to 12 degrees. The landing roll-out was 260 feet. The vehicle was undamaged. The flight duration was 18 minutes.

Flight Operation 180-9 - This is a continuation of objectives sought in previous flight. Takeoff was from the drop zone for the first time and was satisfactory. The speed envelope for 14 degrees and 16 degrees wing incidence was determined as 30-40 knots. A good landing on the drop zone was made at a 30-knot approach speed. No damage was sustained by the vehicle. The flight duration was 18 minutes. The tow helicopter was the CH-34C.

Flight Operation 180-10 - The test objective was to check glider flight characteristics with maximum gross weight of 2, 245 pounds (1, 500-pound payload). The takeoff roll was satisfactory. Rotation at 55 knots was smooth on lift-off but the vehicle continued to rotate to 75-80 degrees nose up attitude. Three severe pitch oscillations resulted in the weak link's breaking. The glider landed in a level flight attitude on the active runway. The platform of the glider sustained major damage. Other components sustained minor damage. The glider was repairable. Pitch up was due to a combination of improper tow bridle rigging and wing incidence.

Flight Operation 180-11 - Test objectives were to check flight characteristics of LUG No. 2. The gross weight was 1, 124 pounds. Takeoff and landing were accomplished on the active runway. The established flight envelope was the same as for the LUG No. 1. The glider made a good on-tow landing. Flight duration was 31 minutes.

Flight Operation 180-12. The test objective was to make a demonstration flight for visiting German military personnel. The flight configuration was identical to flight operation 180-11. Takeoff and landing were good on the active runway. Flight duration was 13 minutes.

Flight Operation 180-13 Test objectives were to check the glider flight envelope at 1,130 pounds' gross weight and forward center-of-gravity position. The takeoff was good. Speed envelope was expanded to 60 knots. The right-hand landing gear steering tie rod broke on landing. Flight duration was 32 minutes.

Flight Operation 180-14 - The test objective was to check the flight envelope with new tow bridle geometry on glider. The glider gross weight was 1,131 pounds. The takeoff and landing were good. The speed envelope was expanded to 70 knots.

Flight Operation 180-15 - Test objective was to check flight characteristics with 1,000 pound payload, 1,782 pound gross weight. The configuration was identical to flight operation 180-14. The takeoff, climb, and cruise were good. The maximum speed attained was 70 knots. The minimum speed was 55 knots, which was limited by pitch oscillations. The landing approach was made at 55 knots, which resulted in excessive floating. A go-around was attempted too late and resulted in the glider's hitting a tree. Considerable damage was sustained by the wing and strut system. The right-hand forward rolling gear system sustained major damage. The glider was repairable.

Flight Operation 180-16 - Test objectives were to determine the flight envelope under tow at maximum gross weight of 1,500 pounds' payload. The glider gross weight was 2,245 pounds. A good lift-off was made and good tow characteristics were evidenced at 14 degrees wing incidence. The speed range was 55 to 70 knots. The landing was made on the drop zone. The glider contacted the ground rear wheels first and was immediately disconnected from the tow cable. The front end then pitched down severely and the right-hand skid dug into the ground causing the glider to nose over onto the wing. Major damage was sustained by the wing and wing supports. The body was damaged at the right front wheel.

Flight Operation 180-17 - Test objectives were to determine towed flight characteristics with the new tow bridle geometry and minimum weight LUG No. 4. A good lift-off was made utilizing the CH-34C. Tow speeds were found to be between 30 and 55 knots with wing incidence at 10 degrees to 12 degrees. A good landing was made on the drop zone without damage.

Flight Operation 180-18 - Test objectives were to indoctrinate the Bell Aircraft civilian pilot in tow techniques and to evaluate the tow bridle installation on the UH-1B helicopter. Static pull tests were made before takeoff. Cable-only flights were made satisfactorily.

Flight Operation 180-19 - Test objectives were to determine tow characteristics of the glider at minimum gross weight using the UH-1B helicopter. A good takeoff, flight, and landing were made on the active runway. Two characteristics were proven to be the same as with CH-34C.

Flight Operation 180-20 - Test objectives were to determine UH-1B tow characteristics with a 350-pound payload (1,115 pounds' gross weight). A good takeoff was made from the active runway. The glider was towed to the drop zone where a good landing was made. Minor damage was sustained by the tie rod. Flight characteristics with the UH-1B helicopter were similar to that for the CH-34C.

Flight Operation 180-21 - Test objectives were to determine free flignt characteristics with a minimum weight glider. LUG No. 4 was towed off the active runway to the drop zone by the CH-34C helicopter. The glider was released in the vicinity of the drop zone at 3, 500-foot altitude. The gross weight of the glider was 775 pounds. The wing incidence was set at 14 degrees for free flight and released at 45 knots. A 28-minute tow mission was flown before glider release. The glider evidenced extremely poor roll control resolution. This is attributed to the high roll rate of the electro-mechanical directional control system. The glider landed off the drop zone in a small clearing with a diminishing right roll maneuver. Landing roll-out was approximately 120 feet. Free flight glide time was 3 minutes and 10 seconds. Minor damage was sustained by the tie rod.

Flight Operation 180-22 - Test objectives were to determine towed flight characteristics of the glider with a 750-pound payload using the UH-1B helicopter. A good takeoff, 35-minute flight, and landing were made. The speed envelope varied from a minimum of 35 knots at 18 degrees wing angle to 70 knots with a 10 degree wing angle.

Flight Operation 180-23 - The test objective was to check glider flight characteristics with a 1, 200-pound payload, 1, 990 pounds' gross weight. The tow helicopter was the UH-1B. A good takeoff and landing were made. The cruise speed range was from 40 to 70 knots, and flight time was 35 minutes. The left tie rod bent on landing. The Bell test pilot flying the UH-1B reported helicopter handling characteristics to be satisfactory.

Flight Operation 180-24 - The test objective was to check glider and UH-1B flight characteristics with a 1,500-pound glider payload. The takeoff roll was 1,450 feet. A pitch oscillation was again experienced at lift-off. Cruise speed range was 45 to 70 knots. Some neutrally damped pitch oscillations were experienced at low speed and low wing-incidence angles. A good landing was made with a 260-foot roll-out. Pending final tail rotor loads analysis, this flight should complete certification of the UH-1B helicopter as a tow vehicle.

Flight Operation 180-25 - The test objective was to tow the glider with a 75 mm howitzer as payload, with a gross weight of 2,216 pounds. LUG No. 3 was towed by the UH-1B tow helicopter. Takeoff and climbout were normal. The cruise speed envelope was the same as the maximum gross weight configuration. Some pitch oscillations were again experienced at 50-55 knots. A good landing was made with a roll-out distance of 265 feet. The flight time was 36 minutes.

Flight Operation 180-26 - The test objective was to free flight the glider with zero payload. The roll control electrical system was reduced to 12 volts to reduce roll rate. The takeoff and climbout were normal. The release altitude was 4,000 feet with 15 degrees wing incidence at 40 knots. Good control was available with trim capability. The landing was good with no damage. The flight time was 30 minutes, including 4 minutes' free flight.

Flight Operation 180-27 - The test objectives were to check free flight characteristics with a 500-pound payload and to evaluate roll control. The voltage to the roll control servo was reduced from 24 to 12 volts in an effort to reduce the roll rate. The flight was made with Glider No. 4; the flare angle was 24.5 degrees, and the flare cable length was 30 feet. The glider was released at 3,400 feet at 45 knots with 16 degrees wing-incidence angle. Severe pitch oscillations resulted after release. The incidence angle was reduced, which damped the oscillations at approximately a 1,500-foot altitude. Roll control was poor, but results were masked by pitch problems. The glider landed a considerable distance from the controller, so flare maneuver was not closely observed. Minor repairable damage occurred on landing. Free flight time was 1 minute 55 seconds.

Flight Operation 180-28 - The test objectives were to free flight the glider with 5-gallon POL containers as payload and to evaluate pitch oscillations at release with a 5-knot lower release speed. Glider No. 4 was used, with a payload of 572 pounds, with a flare angle of 24.5 degrees and a flare cable length of 30 feet. The glider was released at 3,500 feet, at 40 knots and 16 degrees wing-incidence angle. The lower launch speed reduced, but did not eliminate, initial pitch oscillations. The roll control was good. The glider flared at 10 feet of altitude which resulted in a severe pitch up and subsequent nose over. Considerable damage to wing and struts resulted. Free flight time was 1 minute 50 seconds.

Flight Operation 180-29 - The test objectives were: 1) to free flight the glider with a M274 light weapons carrier as payload, 2) to evaluate pitch oscillations at release with the wing-incidence angle lowered to 15 degrees, 3) to evaluate a new mechanical roll control system which reduces the roll rate through a screw jackbell crank arrangement, and 4) to evaluate a 20-foot flare cable. Glider No. 3 with a flare angle of 24.5 degrees was flown. The glider was released at 3,500 feet, at 40 knots and with 15 degrees wing incidence. Only very slight pitch oscillation occurred at release. Roll control was much improved over the previous system. The glider flared at 2-3 feet above ground. The result was again a severe pitch up followed by nosing over. The wing struts were damaged considerably. Free flight time was 2 minutes. The conclusion was that a 24.5 degrees flare angle is too great. This will be reduced to 20 degrees for the next flight.

Flight Operation 180-30 - The test objectives were to check the free flight characteristics with a 1,000-pound payload and to evaluate further the roll control system in both the manual and homing modes (mechanical rate limit set at 2 degrees/sec). The flight was made with Glider No. 2 with a gross weight of 1,815 pounds. Takeoff and climb to altitude were normal. During the free flight check, the flare pendant could not be deployed. The free flight portion of the mission was cancelled and the glider landed on tow with no damage. The flight time was 27 minutes. Post-flight inspection showed that the flare pendant hung up on a piece of tape after it had been released electrically.

Flight Operation 180-31 - After correcting the flare pendant release problem, the same glider was taken off from the drop zone for the purpose of obtaining the objectives of the previous flight. The glider was launched from 3,500 feet at 45 knots and a 15 degree wing-incidence angle. No pitch oscillations were encountered after release. Good roll control was experienced in the manual mode. During the homing check, the glider went into a tight spiral. The control was switched to manual, and recovery was attempted but not achieved. The glider was demolished on impact. Flight time was 17 minutes, including 1 minute 4 seconds of free flight.

Flight Operation 180-32 - The test objectives were to check the free flight control characteristics with both manual and homing control with a zero glider payload. Manual roll control limits were ±4-1/2 degrees and homing roll control limits were ±1 degree. The flare cable length was 20 feet. The take-off and flight to altitude were normal. The glider was released at 3,500 feet, 40 knots and 15 degree wing incidence. Manual roll control was good with adequate trim capability. A 15-second homing check indicated that 1 degree of roll did not produce sufficient roll power for turns. The flare and landing maneuvers were satisfactory. No damage occurred on landing.

Flight Operation 180-33 - The test objectives were to check the free flight characteristics with a 500-pound payload. The vehicle configuration was the same as for the previous flight except for a 2.3-inch aft center-of-gravity movement. The glider was released at 3,500-foot altitude, 45 knots and 15 degree wing incidence. After launch, the glider pitched up; this was followed by a steep right turn and a series of stalls. The wing incidence was brought down approximately 1 degree and the stalls damped out. Roll control appeared to be more sensitive at this gross weight. The final turn resulted in excessive altitude loss and the glider crashed while still in the turn. The platform and wing assembly were damaged extensively.

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4. Ryan Aeronautical Company, Flexible Wing Air Cargo Delivery System Final Program Report, Ryan Report 63B109, 31 October 1963.

5. Dwinnell, G. H., Principles of Aerodynamics, McGraw-Hill Book Co., Inc. New York, 1949.

APPENDIX I - MAJOR MODIFICATIONS

FTO	MODIFICATION
180-1	Installed new front wheel caster fittings.
180-2	Installed new spreader bar center section.
180-10	Added 4.5 inches to forward A-frame pitch actuator.
180-13	Forward lateral channel strengthened on outboard ends of platform.
180-14	Moved tow bridle guides up 10 inches on forward A-frame.
180-21	Modified roll control system by installing new cables with longer cams; relocated left limit switch to right side of platform; and installed springs in inboard end of cam tubes to maintain cable tension.
	Installed cable keepers on drum.
180-25	Installed 14-second delay in flare pendant deployment systems.
180-26	Reduced roll actuator voltage to 12 volts.
180-27	Flare pendant length increased to 30 feet.
180-29	Installed mechanical roll system. Roll rate = 2 degrees/second.
180-32	Homing roll limits set at ± 1 degree.
	Installed helicopter guard hook assembly and weak link protectors.

APPENDIX II — LUG CONFIGURATION AND RESULTS SUMMARY

				CONFIGURATION												
FTO-180	DATE	WING NO.	BODY NO.	GR. WT. LBS.	CG	WING INC. DEG.	FLARE INC. DEG.	PENDANT LENGTH FT.	PENDANT WT. LBS.	BANK ANGLE DEG.	HOME BANK ANGLE DEG.	TOW LINE TENSION LBS.	ALT. DIFF. FT.	A/S KIAS	MSL ALT. FT.
-1 (T)	7/23/64	None	1	917									N/A	N/A	N/A
-2 (T)	7/25/64	1	1	1115	144	10							N/A	N/A	N/A
-3 (T)	7/26/64	1	1	1115	144	10-18							N/A	N/A	N/A
-4	7/28/64	1	1	1115	144	10.5-18	24	20	3.5	±4-1/2		Not Working	275-300		1500
-5	7/31/64	1	1	1115	144	10.5-18	24	20	3.5	±4-1/2		300-500	0-300	35-50	1500
-6	7/31/64	1	1	1115	152	10.5-18	24	20	3.5	±4-1/2					
-7	8/4/64	1	1	1539	144.1	10.5-18	24	20	3.5	±4-1/2		420-680	75-300	30-60	2000
-8	8/5/64	1	1	774.5	143.35	10.5-18	24	20	3.5	±4-1/2		270-380	50-300	35-50	2000
-9	8/5/64	1	1	774.5	143.35	10.5-18	24	20	3.5	±4-1/2		220-320	50-225	30-50	2000
-10	8/8/64	1	1	2287	145.8	10-22	24	20	3.5	±4-1/2					
-11	8/12/64	2	2	1124	144.3	10-18				±4		300-460	0-300	35-55	1500
-12	8/12/64	2	2	1124	144.3	10-18				±4					
-13	8/14/64	2	2	1131	140.0	10-18				±4		280-480	75-300	35-65	2000
-14	8/15/64	2	2	1131	144.3	10-18				±4		320-520	[illegible]0-300	35-70	
-15	8/17/64	2	2	1782	145.9	10-19				±4		470-600	50-250	55-75	1500
-16	8/19/64	3	3	2242	145.2	10-23				±4-1/2		560-660	50-250	55-70	2000
-17	8/21/64	4	4	790	142.9	10-18				±4		240-340	75-325	30-55	2000
-18 (C)	8/21/64	Tow Cable Only													
-19	8/22/64	4	4	790	142.9	10-18				±4-1/2		Not Working	75-350	30-55	2000
-20	8/22/64	4	4	1134	144.3	10-18				±4-1/2		Not Working	25-275	35-75	2000
-21	8/24/64	4	4	790	142.9	10-18	24.5	20	3.5	±4-1/2	±4-1/2		50	40	4000
-22	8/25/64	1	3	1534	144.1	10-18				±4-1/2		400-720	50-325	35-70	2000
-23	8/26/64	1	3	1990	145.7	10-20				±4-1/2		620-840	25-375	40-75	2000
-24	8/27/64	1	3	2282	145.7	10-20				±4-1/2		720-1040	0-350	45-70	2000
-25	8/28/64	1	3	2216	145.5	10-20				±4-1/2		700-1080	50-225	45-70	2000
-26	8/28/64	4	4	790	142.9	10-18	24.5	20	3.5	±4-1/2	±4-1/2	320-420	100-250	40-50	4500
-27	8/29/64	4	4	1298	144.7	10-18	24.5	30	3.5	±4-1/2	±4-1/2		100	45	4100
-28	8/30/64	4	4	1362	144.7	10-18	24.5	30	3.5	±4-1/2	±4-1/2	500-640	75-300	35-55	4000
-29	8/30/64	1	2	1513	144.9	10-18	24.5	20	3.5	±4-1/2	±4-1/2	500-600	75-300	40-55	4000
-30	9/1/64	1	2	1815	146.2	10-18	20	2[illegible]	3.5	±4-1/2	±4-1/2		250	50	2000
-31	9/1/64	1	2	1815	146.2	10-18	20	25	3.5	±4-1/2	±4-1/2		200	50	4000
-32	9/17/64	3	3	792	142.5	10-18	20	20	3.5	±4-1/2	±1			40	4000
-33	9/17/64	4	4	1318	144.8	10-18	20	20	3.5	±4	±1			45	4000

A

LUG CONFIGURATION AND RESULTS SUMMARY

	PERFORMANCE															
				HELICOPTER					GROUND ROLL IN FT.		WIND					
BANK ANGLE DEG.	HOME BANK ANGLE DEG.	TOW LINE TENSION LBS.	ALT. DIFF. FT.	A/S KIAS	MSL ALT. FT.	TEMP. °C	MAP OR TORQUE	H. P.	T. O.	LDG.	DIR. DEG.	VEL. (KNOTS)	GRND. TEMP.	PHOTO COVER	FLT. TIME	
			N/A	N/A	N/A	N/A	N/A	N/A						YES		Truck tow - 350' c
			N/A	N/A	N/A	N/A	N/A	N/A			N	0-6	90	YES		Truck tow - Wing
			N/A	N/A	N/A	N/A	N/A	N/A			Lt. & Var.		82	YES		Truck tow - Eight
±4-1/2		Not Working	275-300		1500				1000	265	330	2-3	90	YES	:42	Helo tow-on LDG.
±4-1/2		300-500	0-300	35-50	1500	25	28-30		1000	225	CALM		80	NO	:29	Helo tow-on LDG.
±4-1/2									320	20	110	5-7	85	NO	:01	Divergent dutch ro
±4-1/2		420-680	75-300	30-60	2000	28	28-33		1700	250	210	7-9	90	NO	:55	Check speed envel
±4-1/2		270-380	50-300	35-50	2000	26	28.5-29		900	260	CALM		85	YES	:25	Check speed envel
±4-1/2		220-320	50-225	30-50	2000	28	28.5-30		580	170	CALM		90	YES	:18	Check speed envel
±4-1/2									1300	230	260	2-3	90	NO	:01	Max. Gross - Pitc
±4		300-460	0-300	35-55	1500	29	29-32		1300	230	CALM		85	NO	:31	Check flt. for S/N
±4									800	175	180	9-10	105	YES	:13	Demo flt. for west
±4		280-480	75-300	35-65	2000	25/26	27-31	665	1250	95	060	5-10	86	NO	:32	A/S vs. i_w = 12°,
±4		320-520	50-300	35-70		26/27	27-31	665	1100	175	090	3-7	80	NO	:38	Tow bridle moved
±4		470-600	50-250	55-75	1500	29	30-33.5	750	1750	480	CALM		85	NO	:34	A/S vs i_w = 12°,
±4-1/2		560-660	50-250	55-70	2000	30	31.5-34	735	1800	78	CALM		85	NO	:48	A/S vs i_w = 16',
±4		240-340	75-325	30-55	2000	27	28-30	665	1400	175	CALM		90	YES	:34	A/S vs i_w = 10°,
											CALM		105	YES	:20	Tow bridle checkou
±4-1/2		Not Working	75-350	30-55	2000	29	19-21.5	465	1350	330	CALM		85	YES	:25	1st tow W/UH-1B -
±4-1/2		Not Working	25-275	35-75	2000	29	18.5-27.5	550	1350	330	CALM		95	YES	:33	A/S vs i_w = 10°,
±4-1/2	±4-1/2		50	40	4000				800	110	060	2-6	85	YES	:28	First free flight -
±4-1/2		400-720	50-325	35-70	2000	26/28	17-27	550	1325	150	080	2-5	90	YES	:35	A/S vs i_w = 10°,
±4-1/2		620-840	25-375	40-75	2000	28	21.5-27	575	1300	410	CALM		90	YES	:35	A/S vs i_w = 15°,
±4-1/2		720-1040	0-350	45-70	2000	25/26	27-28	575	1450	260	070	7-9	85	NO	:34	A/S vs i_w = 16°,
±4-1/2		700-1080	50-225	45-70	2000	25	23.5-28.5	575	1600	265	075	5-6	85	YES	:36	75mm Howitzer -
±4-1/2	±4-1/2	320-420	100-250	40-50	4500				875	66	CALM		95	YES	:30	2nd free flt. - Red
±4-1/2	±4-1/2		100	45	4100				1250	70	120	2-3	80	NO	:19	3rd free flt. - Exc
±4-1/2	±4-1/2	500-640	75-300	35-55	4000				625	24	070	7-8	75	NO	:20	4th free flt.- Fair
±4-1/2	±4-1/2	500-600	75-300	40-55	4000	26	19.5-22		700	25	CALM		95	NO	:19	5th free flt.- Good
±4-1/2	±4-1/2		250	50	2000				1100	400	CALM		90	NO	:27	Planned free flt.
±4-1/2	±4-1/2		200	50	4000				800		CALM		90	NO	:17	6th free flt. - Tr
±4-1/2	±1			40	4000				600	165	120	4-5	90	NO	:25	7th free flt. - Goo
±4	±1			45	4000				400	25	260	6-8		NO	:19	8th free flt. - pit

B

RY

WIND		GRND. TEMP.	PHOTO COVER	FLT. TIME	COMMENTS ON STABILITY, REMOTE COMMANDS AND HOMING
DIR. DEG.	VEL. (KNOTS)				
			YES		Truck tow - 350' cable - Satisfactory up to 40 MPH
N	0-6	90	YES		Truck tow - Wing installed, one run to 25 MPH, quit due to gusts
Lt. & Var.		82	YES		Truck tow - Eight runs, front wheel lift-off at 52 MPH & $i_w = 18°$ - All O.K.
330	2-3	90	YES	:42	Helo tow-on LDG. - Shake down flt. & Demonstration - Appeared stable - i_w 14° flt. & LDG. H-34 Tow
CALM		80	NO	:29	Helo tow-on LDG. - Check speed envelope for $i_w = 14°$, 10°, & 18° - Good Landing H-34 Tow
110	5-7	85	NO	:01	Divergent dutch roll following lift-off ABORTED - Only minor damage - One strut H-34 Tow
210	7-9	90	NO	:55	Check speed envelope for $i_w = 10°$, 12°, 14°, 13° & 18° for this G.W. & C.G. H-34 Tow
CALM		85	YES	:25	Check speed envelope for $i_w = 12°$ & 10° for empty wt. H-34 Tow
CALM		90	YES	:18	Check speed envelope for $i_w = 14°$ & 16° for empty wt. H-34 Tow
260	2-3	90	NO	:01	Max. Gross - Pitch osc. after lift-off broke weak link - Hard LDG. - Major damage H-34 Tow
CALM		85	NO	:31	Check flt. for S/N 2 & A/S vs $i_w = 12°$, 14° & 16° for this wt. & C.G. H-34 Tow
180	9-10	105	YES	:13	Demo flt. for west German General & Staff - Take-off, fly-by & tow-on LDG. on runway H-34 Tow
060	5-10	86	NO	:32	A/S vs. $i_w = 12°$, 14° & 16° for fwd. C.G., - Airborne remote radio check from GND. control - O.K. H-34 Tow
090	3-7	80	NO	:38	Tow bridle moved up 10" - Greatly improved envelope H-34 Tow
CALM		85	NO	:34	A/S vs $i_w = 12°$, 14° & 16° - Hard landing into brush from about 30' - Major damage H-34 Tow
CALM		85	NO	:48	A/S vs i_w = 16', 14° & 18° - Released too high & nosed over after impact - major damage H-34 Tow
CALM		90	YES	:34	A/S vs $i_w = 10°$, 12° & 14° for empty wt. & C.G. - Good flt. & LDG. - No damage H-34 Tow
CALM		105	YES	:20	Tow bridle checkout on UH-1B with tow cable only - All O.K. up to 70 KIAS UH-1B Tow
CALM		85	YES	:25	1st tow W/UH-1B - A/S vs $i_w = 10°$, 12° & 14° - Good flt. & LDG. - No damage UH-1B Tow
CALM		95	YES	:33	A/S vs $i_w = 10°$, 12°, 14° & 16° - Good flt. & LDG. - Agrees with envelope on H-34 UH-1B Tow
060	2-6	85	YES	:28	First free flight - roll rate too fast for positive control - Good LDG. - 3'10" free flt. time H-34 Tow
080	2-5	90	YES	:35	A/S vs $i_w = 10°$, 12°, 14 & 16° - Envelope improved for this G.W. with tow bridle raised 10". UH-1B tow
CALM		90	YES	:35	A/S vs $i_w = 15°$, 13°, 11° & 17° - 1st flight for this gross wt. - Good envelope - UH-1B tow
070	7-9	85	NO	:34	A/S vs $i_w = 16°$, 14°, 12° & 18° - Max. gross wt. - Good tow-on LDG - No damage UH-1B Tow
075	5-6	85	YES	:36	75mm Howitzer - Envelope compared well for this wt. - Good tow-on LDG - Hit DZ marker - Minor damage UH-1B Tow
CALM		95	YES	:30	2nd free flt. - Reduced roll servo voltage to 12-V made roll control possible - 4 min. free flt. time UH-1B Tow
120	2-3	80	NO	:19	3rd free flt. - Excessive porpoising (pitch osc.) - Marginal roll control - 1'55" free flt. time UH-1B Tow
070	7-8	75	NO	:20	4th free flt.- Fair flt. with slightly better roll control - Nosed over on LDG - 1'50" free flt. time UH-1B Tow
CALM		95	NO	:19	5th free flt.- Good roll control (Mech. Sys.) - Nosed over on LDG - Too much flare - 2' free flt. time UH-1B Tow
CALM		90	NO	:27	Planned free flt. - Changed to tow-on LDG., because flare pendant would not deploy H-34 Tow
CALM		90	NO	:17	6th free flt. - Tried homing - Too steep bank caused tight spiral - crashed - 1'4" free flt. time H-34 Tow
120	4-5	90	NO	:25	7th free flt. - Good manual control, not enough homing, good LDG, no damage - 2'12" free flt. time UH-1B Tow
260	6-8		NO	:19	8th free flt. - pitch-up at release, series of stalls, landed in a turn, demolished - 2'6" free flt. time UH-1B Tow

C

APPENDIX III - OBSERVED TOW FLIGHT DATA

The following symbols appear in the data starting on the next page:

T.O. = takeoff

KIAS = knots indicated airspeed

i_w = LUG wing-incidence angle

OBS TENS = tow cable tension

$\measuredangle_D$ = cable angle with respect to helicopter

$\measuredangle_h$ = differential altitude between helicopter and LUG

MAP = manifold air pressure of helicopter engine

OAT = outside air temperature

= pounds

LDG = landing

FPM = feet per minute

LOF = lift-off

LT = light

LAT = lateral

OSCIL = oscillation

R/D = rate of descent

TORK = helicopter torque

OBSERVED TOW FLIGHT DATA

Flt. No.	Cond.	i_w (deg.)	KIAS	Obs. Tens (lb)	λ_D (deg.)	λ_h (ft.)	MAP (in. Hg.)	OAT (°C)	Remarks
180-8	T.O.	16	50		–	–	44	28	–
	Climb	12	50	360	20	100	32	28	–
	Climb	14	50	380	10	50	32	27	Too high
	Level	12	45	70	30	150	29	26	–
	Level	–	50	330	5	50	29	26	–
	Level	–	40	280	30	150	28.5	26	–
	Level	–	35	390	60	275	28.5	26	–
	Level	10	40	320	50	250	29	26	–
	Level	–	35	280	75	300	29	26	–
	Level	–	45	320	30	200	29	26	–
	Level	–	50	340	15	75	29	26	–
	Desc.	10	40	–	–	–	27	26	–
	Ldg.	12	35	–	–	–	–	–	–
180-9	T.O.	16	50		–	–	46	32	–
	Climb	12	50	–	–	–	32	30	–
	Level	14	40	220	40	200	29	28	Turn C.
	Level	–	45	320	5	25	29	28	–
	Level	–	35	300	20	100	28.5	28	–
	Level	–	30	240	50	225	28	28	–
	Level	16	30	200	–	–	29	28	–
	Level	–	35	240	50	225	30	28	–
	Level	–	40	320	5	50	30	28	High
	Ldg.	12	30			–	27.5	30	–
180-10	T.O.	22	55		–	–	–	–	Pitch up to 75 - 80°, climb and pitch oscil. Broke weak link after takeoff.
180-11	T.O.	18	50	–	–	–	42	30	–
	Climb	14	55	400	20	75	35	30	–
	Level	14	50	340		75	29	29	Lt. lat. oscil.
	–	–	55	380	–	–	30	29	Too high
	–	–	40	310	45	200	29	29	–
	–	–	35	340	75	300	30	29	–
	–	16	35	460	45	200	32	29	–
	–	–	45	320	20	150	31	29	–
	–	–	50	–	–	–	–	–	Too high
	–	12	45	–	–	–	–	28	Lt. pitch oscil.
	–	–	60	–	–	–	–	–	Too high
	Desc.	14	40	300	20	100	28	29, 30	200
	Ldg.	14	40	–	–	–	–	–	Runway 35
180-12	T.O. (demo flight)	18	55	–	–	–	–	–	Runway 17
180-13	T.O.	18	55	–	–	–	40	30	–
	Climb	14	55	360	30	150	36	29	–
	Level	14	45	380	50	250	31	28	–
	–	–	50	380	–	–	31	27	–

OBSERVED TOW FLIGHT DATA

Flt. No.	Cond.	i_w (deg.)	KIAS	Obs. Tens (lb.)	$\angle \lambda_D$ (deg.)	$- \lambda_b$ (ft.)	MAP (in. Hg.)	OAT (°C)	Remarks
180-13	–	–	55	400	30	150	30	26	–
(Cont)	–	–	60	440	5	50	30	26	High ride
	–	12	60	480	15	75	30	26	–
	–	–	65	–	–	–	–	–	Towing oscil.
	–	–	50	–	–	–	29	26	Pitch oscil.
	–	16	45	380	20	100	29	26	–
	–	–	50	340	15	75	29	26	Lat. oscil.
	–	–	40	280	45	250	29	25	–
	–	–	35	300	60	300	27	25	–
	Fly-by	14	42	320			25	28	Some pitch oscil.
	Ldg.	14	45	320	30	150	26	28	1-2°
180-14	T.O.	18	50	–	–	–	46		–
	Climb	14	55	410	45	260	[illegible]	28	–
	Level	14	60	390	15	150	31	27	–
	–	–	65	–	–	–	–	–	Too high
	–	–	50	390	20	100	29	27	–
	–	–	45	330	45	200	28	27	–
	–	–	40	330	75	300	28	27	–
	–	–	35	420	80	300	30	27	–
	–	16	35	420	70	275	31	26	–
	–	–	40	460	60	250	31	26	–
	–	–	45	360	35	150	28	26	–
	–	–	50	320	10	50	28	26	–
	–	12	50	390	30	175	28	26	–
	–	–	55	400	20	150	28	26	–
	–	–	60	420	15	75	28	26	–
	–	–	65	–	10	50	30	26	–
	–	10.5	65	500	30	150	30	26	–
	–	–	70	520	10	50	31	27	–
	–	–	50	390	40	200	27	27	–
	–	–	45	360-400	60	300	–	–	Pitch oscil.
	–	12	45	–	–	–	–	–	Pitch oscil.
	Fly-by	14	42	–	–	–	27	28	50
	Ldg.	14	45	–	–	–	–	–	–
180-15	T.O.	19	55	–	–	–	45	31	–
	Climb	14	60	580	45	200	36	30	Stable
	Level	14	55	500	30	150	30	28	–
	–	–	60	470	15	100	30.5	28	–
	–	–	65	500	10	75	32.2	29	–
	–	–	70	600	5	50	33.5	29	High
	–	12	70	570	15	100	32.5	29	–
	–	–	75	–	–	–	33.5	29	Too high
	–	–	50	520	–	–	30.0	29	Pitch oscil.
	–	–	55	–	45	200	30.0	29	Pitch oscil.
	–	–	60	520	–	–	31.5	29	Set. oscil.
	–	14	60	520	45	200	30.5	29	–
	–	–	55	480	50	250	30.0	29	Pitch oscil.
	Level	16	55	470	20	125	29.5	29	–
	–	–	60	520	20		30.5	29	Spontaneous

OBSERVED TOW FLIGHT DATA

Flt. No.	Cond.	i_w (deg.)	KIAS	Obs. Tens (lb.)	$\measuredangle \gamma_D$ (deg.)	$\measuredangle \gamma_h$ (ft.)	MAP (in. Hg.)	OAT (°C)	Remarks
180-15	–	–	50	540	–	–	30.5	29	Pitch oscil.
(Cont)	Desc.	16	55	420	15	100	30.0	28	200 fpm R/D
	Ldg.	14	55	–	–	–	–	–	–
180-16	T.O.	20	55	800	–	–	47	30	(1) Pitch cycle
	Climb	16	65	780	20	150	38	30	–
	Level	16	55	560/600	45	250	33	30	Slt. pitch oscil.
	–	16	60	660	30	200	33	30	–
	–	16	65	600	5	50	33	30	Too high
	–	14	65	600	15	100	32.5	30	–
	–	–	70	600	5	50	34	30	Too high
	–	–	55	–	–	–	31.5	30	Pitch oscil.
	–	–	60	620	45	200	32	30	OK
	–	18	55	–	–	–	32	30	Pitch oscil.
	–	–	60	–	–	–	–	–	Too high
	Desc.	16	55	540	20	125	–	30	300 fpm R/D
	2 pass	16	52	–	–	–	–	–	–
	Ldg.	16	52	–	–	–	–	–	–
180-17	T.O.	16	45	–	–	–	43	28	–
	Climb	12	50	320	45	275	32	28	Stable
	Level	14	50	330	10	75	30	28	Lat. oscil and T.L
	–	12	50	310	25	100	30	28	Stable
	–	10	50	340	35	125	30	27	Stable
	–	10	55	300	10	75	30	27	Stable
	Turn	10	50	340	30	100	30	27	Good
	Level	10	45	300	45	200	28	27	Stable
	–	10	40	280	60	275	28	27	–
	–	10	35	290	75	325	28	27	–
	–	12	35	260	35	200	[illegible]	27	–
	–	12	30	260	45	300	28	27	–
	–	14	30	240	30	200	28	27	–
	Desc.	12	37	–	35	200	–	–	–
	Ldg.	12	35	280	40	225	–	–	–
180-19	T.O.	16	40	–	–	–	30	28	–
	Climb	12	45	–	45	200	30	28	–
	Climb	12	50	–	35	150	–	–	–
	Level	14	45	–	15	75	21	29	–
	–	12	50	–	10	50	21.5	29	Same stick
	–	10	55	–	15	75	21.5	29	Same stick
	–	10	40	–	45	200	19	29	–
	–	10	35	–	70	375	19	29	–
	–	12	35	–	50	250	20	29	–
	–	12	30	–	75	350	20	29	–
	–	14	30	–	45	200	20	29	–
	Desc.	12	35	–	–	–	–	–	200 fpm OK
	Ldg.	12	35	–	–	–	–	–	First pass
180-20	T.O.	18	60	–	–	–	31	30	–
	Climb	14	55	–	45	225	28.5	30	–
	Level	16	45	–	–	–	20	29	–

OBSERVED TOW FLIGHT DATA

Flt. No.	Cond.	i_w (deg.)	KIAS	Tow Ten (lb.)	Δ_D (deg.	Δ_H (ft.)	TORK (ft. L.E.)	OAT (°C)	Remarks
180-20	–	16	50	–	15	75	20	29	–
(Cont)	–	14	50	–	–	–	20	29	–
	–	–	55	–	–	–	21	29	–
	–	–	60	–	8	50	21.5	29	–
	–	12	60	–	15	100	22	29	–
	–	12	65	–	5	25	24	29	Too high
	–	10	60	–	–	–	22	29	–
	–	12	50	–	–	–	21	29	–
	–	10	65	–	20	125	25	29	–
	–	–	70	–	10	50	26	29	–
	–	–	75	–	5	25	27.5	29	Too high
	–	–	50	–	60	275	21	29	Slt. pitch oscil.
	–	–	50	–	–	–	21	–	–
	–	12	45	–	50	250	20	29	–
	–	14	35	–	50	250	18.5	30	–
	–	16	35	–	45	275	22	30	–
	Desc.	14	40	–	35	275	16	29	–
	Ldg.	14	40	–	–	–	–	–	–
180-22	T.O.	18	50	–	–	–	35	29	Wing Fill-10 KIAS
	Climb	14	55	720	45	200	33	28	–
	Climb	14	60	680	20	150	32	28	Better for Climb
	Level	14	55	530	15	100	23	28	–
	–	16	35	620	50	225	24	28	–
	–	–	45	520	30	200	22	28	–
	–	–	50	500	10	50	22	28	–
	–	14	55	540	15	75	23	28	–
	–	14	60	550	10	50	24	28	High but stable
	–	12	65	640	15	75	26	27	–
	Desc.	–	45	500	50	275	17	26	Pitch oscil.
	Level	–	50	400	45	200	22	27	Light pitch oscil.
	–	14	50	–	–	–	–	–	–
	–	–	45	540	45	200	21.5	27	Light pitch oscil.
	–	–	40	540	60	300	21.5	27	Light pitch oscil.
	–	10	55	640	50	225	23	27	Light pitch oscil.
	–	–	50	600	75	325	21.5	27	Pitch oscil.
	–	–	60	620	45	200	22	27	Light pitch oscil.
	–	–	65	640	30	150	24.5	27	Light pitch oscil.
	–	–	70	720	15	100	27	27	Light pitch oscil.
	Desc.	14	40	380	45	200	–	–	200 to 300 fpm
	Ldg.	14	40	–	–	–	–	–	–
180-23	T.O.	19	45	–	–	–	38	28	15° nose down
	Climb	15	55	880	40	175	32	28	–
	Climb	15	60	–	15	100	31	28	–
	Level	15	50	660	30	150	24	28	–
	–	–	45	720	50	225	23.5	28	–
	–	–	40	780	60	275	23	28	–
	–	–	55	620	20	125	24	28	–
	–	–	60	620	3	25	24.5	28	# 1
	–	13	65	660	5	50	25.5	28	–

OBSERVED TOW FLIGHT DATA

Flt No.	Cond.	δ_w (deg.)	KIAS	Tow Ten (lb.)	θ_D (deg.)	Δh (ft.)	TORK (ft. L. E.)	OAT (°C)	Remarks
180-23 (Cont)			50	700	60	300	21.5	28	
		–	45	840	75	350	24	28	Low stable
		11	50	800	80	375	22	28	Low
		–	60	750	45	200	24	28	
	–	–	65	680	30	150	25	28	–
			70	700	15	100	27	28	–
		–	75	–	–		–	–	Too high
	–	17	50	840	20	125	26	28	
	Level	17	55	740	10	50	26	28	High
	–	–	50	–		–	24	28	–
	–		45	720	20	125	23	28	Pitch oscil.
	Desc.	15	45	680	45	200			300 fpm
	Ldg.	15	45			–	–		
180-24	T.O.	20	55	–	–	–	38	27	–
	Climb	16	60	720	30	150	32	27	–
	Climb	16	65	840	15	75	32	26	–
	Level	16	55	800	20	100	26	26	–
			50	840	30	150	25.5	26	–
			45	1040	60	300	28	26	–
			60	720	10	75	25	26	–
			65	–	–	–		–	Co altitude
		11	65	720	10	75	26	25	–
			50	720	45	200	22	25	–
			45	880	75	350	24	25	–
	Turn	12	45						Pitch oscil.
	Level		50	780	50	225	22	25	Pitch oscil.
			60	760	30	150	24	25	Light pitch oscil.
			65	780	15	100	25	25	
			70	800	5	50	28	26	High
			65		–	–	25	26	
		18	45	–	–	–		–	Pitch oscil.
	Desc.	16	50	800	15	100	20	26	200 fpm
	Ldg.	16	50	–	–	–		–	
180-25	T.O.	18	55	900	–		38	26	–
	Climb	16	65	920	10	75	33	26	High
	Climb	16	60	880	20	150	32.5	26	–
	Level	16	55	860	15	100	26	26	–
			45	1080/1120	50	225	26	26	Pitch oscil
			50	840	30	150	26	25	–
			50	780	5	50	26.5	25	–
	–	14	60	700	30	150	23.5	25	–
			65	740	5	50	26	25	High
	–	–	55	840	50	225	26	25	Light pitch oscil.
	–	12	60	780	45	200	25	25	–
	Level	12	65	800	20	100	27.5	25	Random pitch oscil.
			70	800	5	50	28.5	25	High
			65		–	–	26	25	–
	Desc.	16	50	760	15	100	–	–	200 fpm

OBSERVED TOW FLIGHT DATA

Flt. No.	Cond.	i_w (deg.)	KIAS	Tow Ten (lb.)	$\angle\gamma_D$ (deg.)	$\angle\gamma_h$ (ft.)	TORK (ft. L. E.)	OAT (°C)	Remarks
180-25 (Cont)	Desc.	16	48	860	30	150	22		200 fpm - mild high freq. vibration
	1st pass	16	50	–	–	–	–	–	10-12° LUG nose up
	Ldg.	16	50	–	–	–	–	–	–
180-29	T.O.	18	48	–	–	–	35	30	–
	Climb	14	55	640	35	225	30	–	–
	Level	16	35	600	50	300	19.5	26	–
	–	16	50	560	15	75	22	26	–
	–	14	55	580	10	75	22	26	–
	–	14	45	500	45	250	20	26	–
	Launch	15	40	–	–	–	–	–	3400 ft. above terrain

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1 ORIGINATING ACTIVITY (Corporate author) Ryan Aeronautical Company, San Diego, California.	2a REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP
3 REPORT TITLE FLEXIBLE WING LIGHT UTILITY GLIDER	
4 DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Report	
5 AUTHOR(S) (Last name, first name, initial) Sakamoto, N. Cota, G.	
6 REPORT DATE August 1966	7a TOTAL NO OF PAGES 120 / 7b NO OF REFS 5
8a CONTRACT OR GRANT NO DA 44-177-AMC-209(T) b PROJECT NO Task 1F121401A14172 c d	9a ORIGINATOR'S REPORT NUMBER(S) USAAVLABS Technical Report 66-2 9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report) 64B139
10 AVAILABILITY/LIMITATION NOTICES Distribution of this document is unlimited.	
11 SUPPLEMENTARY NOTES none	12 SPONSORING MILITARY ACTIVITY US Army Aviation Materiel Laboratories Fort Eustis, Virginia

13 ABSTRACT

Presented in this report are the results of a flight test program of a towed light utility glider system. The system was designed to carry odd-geometry cargo, and demonstrated towed flight operations up to the maximum design weight of 1500 pounds, at a velocity range extending from 30 to 70 knots indicated airspeed. Testing also included takeoff and landings on tow with helicopters, and evaluation of the flight homing system. Free flights of the light utility glider were also made carrying a payload of 800 pounds.

Presented also are the system description, and an aerodynamics and structural analysis.

Initial phases of the concept were investigated under Contracts DA 44-177-TC-779, DA 44-177-TC-807, and DA 44-177-AMC-868(T).

All flight testing was conducted at the U.S. Army Yuma Proving Ground, Yuma, Arizona, beginning 23 July 1964 and ending 17 September 1964.

DD FORM 1 JAN 64 1473

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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